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(Continuing the Journal of the Allied Dental Societies)

A journal of stomatology; devoted to the advancement and dissemination of knowledge pertaining to the mouth and teeth, and to their relations to the body as a whole

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A Summary of the Titles of the Papers, and the Names, Degrees, and Professional Relationships of the Authors, With Abstracts or Interpretations of the Original Matter in Each Communication

These abstracts are neither editorials nor criticisms; they do not contain comment beyond the scope of the papers to which they refer. They are intended solely to give the reader a general though clear idea of what the corresponding authors have chiefly to say.

(This section of the introductory matter in this volume presents, consecutively, all the abstracts that were published under the head of "contents" at the front of each of the four numbers in the volume. The unrelated miscellaneous items of temporary interest that accompanied the abstracts in the quarterly issues have been eliminated from this presentation of the abstracts.)

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I. Papers in the Main Body of the Volume

Robert Robbin Andrews. An appreciation. By George A. Bates, M.S., D.M.D., Professor of Histology, Medical and Dental Schools, Tufts College, Boston, Mass. 3

Dr. Bates voices the high personal regard in which Dr. Andrews was held by all who knew him. The author refers, in cordial appreciation, to Dr. Andrews' eminent service as one of the pioneers in dental research in this country. Dr. Andrews was one of the founders of the recently organized International Association for Dental Research, and is the first of its members to begin the journey from which no investigator has ever returned. —(W. J. G.)

Food accessory factors in relation to the teeth. By Percy R. Howe, D.M.D., Assistant Professor of Dental Research, Harvard University; Chief of the Research Laboratory, Forsyth Dental Infirmary for Children, Boston, Mass. 7

Howe regards Miller's bacterio-chemical theory of the causation of dental caries as an inadequate explanation of the etiology of this condition. Howe believes, however, that deficiency in

the supply of vitamines, in the diet, may have much to do with the incidence of caries and with the development of extensive decalcification "in the teeth, in the alveolar process, and in the jaws themselves." The experiments he describes were conducted on guinea pigs and rabbits, with diets that were "deficient in each of the three known kinds of vitamines" and strikingly scorbutic in general effect. Howe believes that the fat-free milk in the diets "presumably furnished a sufficient amount of inorganic constituents." Scorbutic effects could be, and were, prevented or repaired, by addition to the diet, when desired, of suitable amounts of antiscorbutic foods such as orange juice.

The entire paper is a condensed review of Howe's work in this relation, and the second half of it (pages 8–11) is an abstract of his publications here and elsewhere on this subject. The legends opposite the twelve plates (fifty figures) indicate directly many of his most significant findings, and the illustrations show at a glance the nature and extent of his most important results. Howe summarizes the significance of his findings in the conclusion that it is his ability "to produce decalcified areas in the bones of the head and in the teeth, with deficient diet, and to effect their recalcification with adequate diet, that is the most striking thing in these experiments."—(W. J. G.)

A study of scurvy and its bearing on the preservation of the teeth. By E. F. Robb, M.D., Graduate Student in Pediatrics, University of Minnesota; Grace Medes, Ph.D., Professor of Physiology, Vassar College, Poughkeepsie, N. Y.; J. F. McClendon, Ph.D., Professor of Physiological Chemistry, University of Minnesota; Margaret Graham, B.A., Technician, University of Minnesota; and I. J. Murphy, M.D., Graduate Student in Physiological Chemistry, University of Minnesota, Minneapolis, Minn. 39

The scope of the research described in this paper is shown by the items in the contents-summary on page 39. The authors "found that the loss of calcium from the body (guinea pigs) was very rapid in (experimental) scurvy. . . . . The teeth . . . became very loose . . . . (indicating) loss of cementum and possibly of material from the alveolar process. . . . . (In these animals with scurvy) there was marked hyperemia of the pulp with some hemorrhage. The odontoblasts lost their tall columnar form and secreted osteodentine

very rapidly. The osteodentine nearly filled the pulp cavity in some cases." The significance of this formation of osteodentine in scurvy is now under investigation.

It was found, further, that an acid-forming diet (which was also a scorbutic diet) caused a depletion of the alkaline reserve of the saliva (and blood) in man, thus impairing the power of the saliva to neutralize oral (fermentation) acidity and presumably reducing the protective action of saliva against caries.

The authors believe that some of their results suggest "that one may suffer (in the teeth) from the effects of a scorbutic diet without showing the characteristic symptoms of scurvy. Therefore, in order to maintain our teeth in good condition, we should make sure that our diet contains sufficient antiscorbutic. As data showing the quantity of meat necessary to prevent human scurvy are not available, and as the antiscorbutic properties of most vegetables seem to be destroyed by canning, we should depend largely for our winter supply of antiscorbutic on cold-storage vegetables and fruits, on canned fruits, tomatoes and rhubarb, and on dried fruits and fruit juices."

The authors state that "raspberry jam is not antiscorbutic. Tomatoes, from jars kept in boiling water one hour, failed to cure a guinea pig of scurvy. Cucumber pickles had no antiscorbutic action, but sweet-pickled peaches that had been in boiling water for twenty minutes and sealed in Mason jars retained antiscorbutic properties. From these facts," the authors conclude that "high temperature, such as that in the making of jam, or prolonged heating like that in the cold-pack process in the home, destroys the antiscorbutics." They believe that, in the preservation of the antiscorbutic power of foods, "hot-pack is preferable to cold-pack, or to preservation by boiling down with sugar, due to the shorter period of exposure to the heat or to the lower temperature." (See the announcement on p. 299.) —(W. J. G.)

The occurrence of hemolytic streptococci about the teeth. By RALPH A. KORDENAT, B.S., M.S., Assistant in Bacteriology, University of Illinois College of Medicine, Chicago, Ill..... 63

Kordenat aimed "to determine more specifically (than heretofore) the frequency in occurrence of various hemolytic streptococci about the teeth and gums in apparently normal, and also in pathological, cases." His methods, described on pages 65–69,

include a new procedure, "clean and painless," for obtaining material from dentogingival spaces. His results were derived from examinations of such material from one hundred and forty-four dispensary and hospital patients. He found that 19.4 per cent of this number of patients "gave positive cultures of hemolytic streptococci." Of the patients with well-defined clinical manifestations of pyorrhea, 31.1 per cent gave positive cultures of hemolytic streptococci, of which three strains were of the S. subacidus group, and four of the S. anginosus. "Hemolytic streptococci were found between the teeth and gums in three of fifteen cases of gingivitis."

Of the various isolated strains of hemolytic streptococci, seventeen were S. anginosus; five, S. subacidus; three, S. hemolyticus-I; two, S. pyogenes; one, S. infrequens; one, S. hemolyticus-III. "Of eleven strains, selected at random from twenty-nine strains of hemolytic streptococci isolated from gingival spaces, two (S. anginosus) proved to be fatal to rabbits in doses of 2 cc. of a broth culture."

"Because of the occurrence of hemolytic streptococci in deep dentogingival spaces, these spaces may be considered to be potentially dangerous foci of infection." There is a possibility that these organisms, proceeding from this site, "act as secondary and terminal invaders. The fact that hemolytic streptococci were found in only a small proportion of the number of cases of pyorrhea examined, and in these not in great numbers, indicates that hemolytic streptococcus is not the primary etiological factor in this condition."—(W. J. G.)

Progressive dentistry and stomatology. 6. Periodontoclasia: Etiology, diagnosis and treatment. By PAUL R. STILLMAN, D.D.S., New York City, President of the American Academy of Periodontology and Officer of Instruction, Advanced Courses in Dentistry, Columbia University; and JOHN OPPIE MCCALL, A.B., D.D.S., Buffalo, N. Y., Officer of Instruction, Advanced Courses in Dentistry, Columbia University..... 73

A scholarly and comprehensive review of the subject to which it relates, with special emphasis on facts (and theories) of etiology, diagnosis, and treatment. "Three fundamental hypotheses" bearing on the etiology of periodontoclasia are presented and defended, namely: (1) "The causes of periclasia are primary or inaugurating, and secondary or non-inaugurating"

(p. 76). (2) "The etiology of any one case of periclasia (except that due to congenital non-occlusion) consists of at least two factors" (p. 76). (3) "The inception and course of periodontal disease are equally under the control of biogenetic and pathogenic forces" (p. 78).

Referring to "the plural character of periclasial etiology," the authors say: "Salivary calculus is frequently found in mouths which appear to be free from disease, thereby apparently eliminating it as a causative factor. Pathogenic bacteria may also be found in healthy mouths and hence seem to be eliminated as a cause of periclasia. Even traumatic occlusion is occasionally found in a mouth in which no disease is to be discovered. But, if traumatic occlusion be combined with lowered tissue-tone, calcareous deposits and bacterial invasion, a suppurative pericementoclasia is the inevitable sequel."

The purposes, principles and procedures of diagnosis are discussed convincingly. Diagnosis "implies more than the recognition and delimitation of the pathological condition; it implies, as well, a determination of the etiological elements involved."

Summarizing their views on treatment, the authors write (p. 85): "The aim of treatment . . . . is to remove the factors that are responsible for the occurrence of the disease, and to give momentum to the biologic forces of repair. It must have its basis in diagnosis of the nature of the lesion and of its causative factors. The intelligent clinician will therefore decide for himself, as he studies his case, when he shall depart from the general plan of treatment, and in what direction this deviation shall proceed." Under concluding remarks" (p. 86), the authors emphasize "two points." "The first relates to the value to be assigned to any type of treatment designed primarily to deal with the bacterial element in periodontoclasia. Vaccines, antiseptics, germicides and treatments intended to increase tissue resistance, are only partially successful at best, and are usually failures. The reason is that the bacterial element is secondary to other factors in the etiology. . . . . The second point, and a most important one, is that in science as in all life, theory must conform to fact, not fact to theory. The reason for our confidence in the truth of the theories herein presented," they add, "is that we have found these theories consistently to conform with the facts."

[See the series of papers on pages 339–352, and the paper on page lix; and note the corrections on page (44).]—(W. J. G.)

The origin and evolution of the human dentition. (A palæontological review; concluded.) **Part V.—Later stages in the evolution of the human dentition; with a final summary and a bibliography.** By WILLIAM K. GREGORY, Ph.D., Associate Professor of Vertebrate Palæontology, Columbia University; Associate in Palæontology, American Museum of Natural History, New York City 87

This concluding part of Gregory's comprehensive review continues directly Part IV, which was published on pages 607 and 718, inclusive, in the December issue of the last preceding volume. The scope of the review may be seen at a glance in the contents-summary on page 87. The author's "summary and conclusions for Part V," beginning on page 197, present a general abstract of this part of the review.

In this concluding section of Gregory's exceptionally valuable and interesting review, the author considers in some detail and broadly the origin and rise of man (p. 88); presents convincingly his own view regarding that origin (in "the transformation of ground apes into men"—p. 109); discusses in a masterly way "the dentition of extinct and of recent Hominidæ" (p. 124); adds a "conspectus of the species and chief races of Hominidæ" (p. 178); and appends a "final summary," for the five parts of the review as a whole, in the form of a condensed statement of the "twenty-six stages in the ascent of man and in the evolution of the human dentition" (p. 206), with a general bibliography (p. 218).

The entire review is an invaluable critical analysis of available facts and current opinion bearing on the origin and evolution of the human dentition; and, because of its comprehensiveness and the eminence and reliability of its authorship, is easily the most important publication on this subject. [See the paper on page 361 and note the corrections on pages (44) and (46.)]

The five parts of this review have been issued in book form. The author has generously arranged for the sale of this book under conditions that will give the proceeds to the Endowment Fund of the JOURNAL OF DENTAL RESEARCH.—(W. J. G.)

Reparative changes that take place about the root-ends of infected pulpless teeth, after treatment. By ARTHUR H. MERRITT, D.D.S., New York City 229

[Merritt's paper was presented for publication before the issuance of the last preceding number of this JOURNAL (Dec., 1920), and without any knowledge on his part of the occurrence of the discussion by Novitzky and Rhein on the same general subject, then soon to be published in that number. The reader should be informed of this fact in order fully to appreciate the independent bearing of Merritt's paper on the said discussion by Novitzky and Rhein.]

Merritt presents the histories of eight cases of periapical infection in each of which the prognosis was regarded as unfavorable. Conditions just before, and long after, treatment are illustrated with twenty-three roentgenograms. "In all cases, tricresol and formalin, as advocated by Buckley, were used for sterilization. No other treatment was employed. Three to five treatments were made. The root canals were filled with chloropercha and gutta-percha points. . . . . Treatment was undertaken with some misgivings. For this reason these cases were kept under observation. In no case has any local or systemic symptom developed, since treatment, that would indicate continuance of infection in these teeth. These cases are reported here for the purpose of showing what may occur in periapically infected teeth, under initially adverse conditions, after treatment."

Merritt agrees with Rhein, and disagrees with Novitzky, in concluding "that, under certain conditions, pulpless teeth may be restored to health and usefulness." His disagreement with Novitzky is noted directly in the addendum to the paper. The first paragraph of the paper (page 229), is, in effect, an abstract of the whole paper.—(W. J. G.)

The Endowment Fund for the support of the Journal of Dental Research. (Ninth report.) By WILLIAM J. GIES..... 239

This statement presents the names of ten new contributors to the Fund, and of seven previous contributors who have again made additions to the Fund. The increase in the amount paid into the fund is $323.00, two hundred and twenty-two contributors having paid $5,144.15, which, with accrued interest ($211.98), makes the Fund a total of $5,356.13. Of this amount, $5,000 are held in U. S. securities at rates of interest ranging from 3.5 per cent to 6 per cent. There have been no expenditures from the

Fund. (The next succeeding report is published on page 299.) —(W. J. G.)

A study of the rate of the interstitial growth of the persistent teeth of the albino rat, as shown by vital dyes. By JOHN S. MARSHALL, M.D., Sc.D., F.A.C.S.; Captain, U. S. A., retired; Research Laboratory, Anatomical Department, University of California, Berkeley, Calif..... 241

This paper is a continuation of the one that appeared in a previous issue of the JOURNAL OF DENTAL RESEARCH (1920, ii, p. 1; March). It deals more particularly with the interstitial, extrusive, and curvative growth of the persistent teeth of the albino rat. In the description of the technic, which precedes the main report of the work, the author states that he found that benzo-dammar is more suitable for the preparation of this type of material than is zylol balsam. Purple, violet, and blue dyes were administered to animals by injection. Alizarine sodium sulphonate, a red dye, was administered by injection and with food.

By careful laboratory record, the author was able to measure the daily rate of the interstitial growth of the dentin, as well as the weekly, extrusive, and curvative growths of the tooth as a whole. Illustrations and protocols substantiate the author's stated findings and conclusions.—(J. A. M.)

Some studies of connective tissues. By GEORGE A. BATES, M.S., D.M.D., Professor of Histology, Medical and Dental Schools, Tufts College, Boston, Mass..... 263

Bates presents a concise, instructive, and well illustrated review of important facts pertaining to the connective tissues (including bone and tooth) of special interest and value to dentists. He discusses successively the development and evolutionary history of connective tissue, the distribution of connective tissue throughout the parts of the body, the relation of periosteum to bone, and the relation of connective tissue to the development and structure of teeth. In the latter section, beginning on page 268, the author refers to histological matters that bear intimately on the solution of problems involved in pyorrhea, apical infections, and nutrition (?) of pulpless teeth, without directly discussing these subjects.

The author's "general conclusions," at the end of the review, are too broad to indicate the wealth of informative and sugges-

tive facts of dental import in all parts of the review, which, to be fully appreciated, must be read in its entirety.—(W. J. G.)

Some American plants considered as sources of vitamines, and as parts of a diet favorable to the preservation of the teeth. By J. F. McClendon, Ph.D., Professor of Physiological Chemistry, University of Minnesota, Medical School, Minneapolis, Minn... 279

McClendon states that Mexicans and North American Indians have exceptionally "good teeth." He believes this condition is "probably due to complete adequacy of diet." He says: "The Indians ate a greater variety of foods than is generally supposed. Their vegetable foods were of such nature, and so preserved and prepared, as to furnish all three classes of vitamines. Since lack of vitamines causes changes in the teeth (scurvy) or improper development of the teeth (rickets), the abundance of vitamines in the diet of Indians probably had much to do with the state of their teeth."

In support of his belief that vitamines play an important rôle in all phases of dentition, and in order to show that the diet of the Indians supplied vitamines in abundance, McClendon mentions many of the plants that were used as food or medicine, or both, by the North American Indians (presumably also by Mexicans), including "tropical American plants that have found their way into the United States and may have done so occasionally in pre-Columbian days. Some of these plants were cultivated by North American Indians, especially corn, beans, pumpkins, and squashes." (McClendon assumes that all the plants he mentions contained vitamines.) The plants are listed, in two groups, in the alphabetic order of their botanical designations, with the corresponding common names in parenthesis.

McClendon's introductory remarks and his concluding discussion emphasize his conviction that vitamines are important factors in normal dentition and that dietary deficiency of vitamines results in serious abnormalities of dentition. His summary on page 294 is a conservative statement of his suggestions, which are "intended to stimulate research along this line." [See the corrections on page (47).]—(W. J. G.)

The Endowment Fund for the support of the Journal of Dental Research. (Tenth report.) By William J. Gies..... 297

This statement presents the names of seven new contributors to the Fund, and of three previous contributors who have again

made additions to the Fund. The increase in the amount paid into the fund is $141.00, two hundred and twenty-nine contributors having paid $5,285.15, which, with accrued interest ($341.85), makes the Fund a total of $5,627.00. Of this amount, $5,200 are held in U. S. securities at rates of interest ranging from 3.5 per cent to 6 per cent. *There have been no expenditures from the Fund.* (The next report is included in the list of "fundors of the JOURNAL OF DENTAL RESEARCH," on page (33) of these introductory pages.)—(W. J. G.)

Prompt announcement and correction of a serious mistake in the binding of the March issue of this Journal. By WILLIAM J. GIES 299

The author refers to, and apologizes for, the accidental omission of pages 53 and 54 from the March number of this volume, when the copies of that issue were bound. The missing pages were appended to the June issue, "to facilitate proper disposition of these two pages in the permanent binding of this volume." —(W. J. G.)

Foreign bodies of dental origin in the bronchus: pulmonary complications. By CARL A. HEDBLOM, M.D., Section on Surgery, Mayo Clinic, Rochester, Minnesota 301

A review of general facts pertaining to the nature of the foreign bodies of dental origin in the fifty-five instances previously recorded in the literature, with a report of three new ones. These foreign bodies were "natural or artificial teeth" in forty-three of the fifty-five previous cases and in two of the three new instances. In the other previous cases (12), the foreign bodies "consisted of materials used in dental operations, such as dentures, fillings, root-canal broaches, burrs, cement, plaster of paris, hard rubber, and (in one case) a broken blade of a forceps;" in one of the three new cases the foreign body was "a silver filling the size of a small kernel of corn, which, according to the dentist, came from a tooth that had not been extracted," nor "treated at the time of the accident."

The author considers the subject briefly and directly under the heads of signs and symptoms, treatment, results, report of cases, and summary. The latter, on page 306, presents his general conclusions. The history of one of Hedblom's new cases (2) lends emphasis to the following opinion attributed to Gardner: "The dentist may, by careful examination of the teeth

before operation, ascertain if the work might displace pieces of tartar, fillings, or even teeth during a general anesthetic. During ether anesthesia, the condition of the patient often requires the use of a gag, and the anesthetist should know the condition of the patient's teeth before the anesthetic is started, since the gag often displaces from teeth foreign bodies which might be inhaled."—(W. J. G.)

Shearer's procedure for the removal of dead teeth and their pathological products, described in 1920, is identical with Novitzky's method for the same purpose, described in 1915. By JOSEF NOVITZKY, D.D.S., San Francisco, California..... 307

Novitzky states that Shearer's operation for "external alveolectomy," published in the *Journal of the National Dental Association* (June, 1920), "is precisely the same as the one I (Novitzky) have been describing and the use of which I have been advocating, since early in the year 1915—a situation that Dr. Shearer has ignored." Novitzky appends a bibliography (1915–1920), relating to his use of the operation, in support of this statement. See the two next succeeding abstracts.—(W. J. G.)

Reply to Novitzky's comment on "Shearer's procedure for the removal of dead teeth and their pathological products." By WILLIAM L. SHEARER, M.D., D.D.S., Professor of Oral Surgery, International School of Orthodontia, Omaha, Nebraska..... 309

Shearer states that he does not claim "originality for the surgical removal of diseased teeth" but does "claim the following: a definite design, known as an 'external alveolectomy' of the upper jaw." He states that he "designed this operation in 1905 for cosmetic purposes only." Later, he "employed this technic, for the eradication of disease of the jaws, when removing teeth, and so advocated this technic in a paper read before the Tri-City Dental Society in Omaha, in April, 1906." A copy of that previously unpublished paper is included in an appendix to Shearer's direct reply, where the reader will find, also, "a copy of the hospital record of an interesting case operated in 1912" (by the technic referred to). See the last preceding and next succeeding abstracts.—(W. J. G.)

Response to Shearer's reply to Novitzky's comment on "Shearer's procedure for the removal of dead teeth and their pathological products." By JOSEF NOVITZKY, D.D.S., San Francisco, California..... 313

Novitzky replies that "aside from the statement about a special forceps, Dr. Shearer's article (1920) contained nothing new; and it contained nothing of value that I (Novitzky) had not previously published several times." Novitzky, alluding to what appears to be a primary element in his attitude, writes as follows: "If, in the description (1920) of his procedure for 'external alveolectomy,' Dr. Shearer had alluded to my prior public presentation of that technique, any scientific purpose his article was intended to subserve would surely have been attained, without detriment to that intention and also without creation of the false impression that something wholly new was being brought forward. If Dr. Shearer's paper had been a statement that the procedure I devised, and *publicly described years ago*, was found by him to be useful, he would have adopted the scientific attitude that every dentist may properly expect of every other. Dr. Shearer has not explained why he ignored *all* the previously published facts in this relation."

Novitzky questions, he says, "the acceptability of a method, or custom, or *partiality*, of publication by which the history of the development of dentistry, in any of its phases, is purposely or indifferently perverted in any manner or to any degree. I assume," he says, "that dentists do not care to be misled into accepting as new anything that is old; and that they expect, when an old procedure is newly presented in a formal way, that reference will suitably be made simultaneously to the original description of that procedure in the literature of the subject."

Novitzky concludes his comment with a discussion in some detail of the contents of the appendix to Shearer's reply. See the last two preceding abstracts.—(W. J. G.)

Oral diagnosis and treatment. The responsibilities of the dentist and the physician. By ELMER S. BEST, D.D.S., non-resident Instructor in Oral Diagnosis, Advanced Courses in Dentistry, Columbia University; and CARL W. WALDRON, M.D., D.D.S., Instructor in Medicine, Clinic of Stomatology, University of Minnesota; both resident in Minneapolis, Minnesota..... 317

The authors discuss effectively and in detail the thesis that "a complete systematic examination of the teeth and investing tissues, followed by a carefully formulated diagnosis, is necessary before dental operative or restorative work can be successfully undertaken." They feel that "a permanent record of this

examination, and the plan of treatment recommended and followed, should be made; and this record should be kept up-to-date by treatment and progress notes, and filed for future reference." Best and Waldron present "a system of oral examination, diagnosis, and principles of practice, which place the oral tissues in a healthy condition; and which, supplemented by oral hygiene and regular observation, maintain this highly desired condition of the mouth." The discussion includes the presentation of "a four-page chart for oral diagnosis, oral prophylaxis, and case records," with an outline of a "plan of treatment." The responsibilities of the dentist and physician to the patient and to each other are considered directly and frankly.

The guiding thought in this paper appears to be expressed in the statements that "the big objective must be *preventive* professional service," and that "the problem today is to encourage and promote the practice of *prophylactic* dentistry."—(W. J. G.)

Progressive dentistry and stomatology. 7. A criticism of the review by Stillman and McCall, on the etiology, diagnosis, and treatment of periodontoclasia. By RAYMONDE A. ALBRAY, D.D.S. Newark, New Jersey..... 339

Albray states that he does not agree with Stillman and McCall (p. 73) in their view "that traumatic occlusion is an etiologic factor in periodontoclasia." Traumatic occlusion, in Albray's view, "may aggravate such a condition already established, but inflammation of the peridental membrane must precede the so-called traumatic occlusion." Albray also dissents from some of the views of Stillman and McCall on the relationship between systemic disorders and periodontal disease, on matters pertaining to the restoration of normal approximal contacts and the use of orthodontic appliances, on the therapeutic effects of cleansing of the tooth surfaces, and in a number of other relations. He concludes with the statement that, "if periodontoclasia could be *cured* as Drs. Stillman and McCall state to the readers of the JOURNAL OF DENTAL RESEARCH it can be done, there would be absolutely no reason to use the word periodontist, for then *every* dentist would be a periodontist." See the two next succeeding abstracts.—(W. J. G.)

Progressive dentistry and stomatology. 8. A response to Albray's criticism of the review by Stillman and McCall, on the etiology, diagnosis, and treatment of periodontoclasia. By PAUL R.

STILLMAN, D.D.S., New York City, Officer of Instruction, Advanced Courses in Dentistry, Columbia University; and JOHN OPPIE MCCALL, A.B., D.D.S., Buffalo, N. Y., non-resident Officer of Instruction, Advanced Courses in Dentistry, Columbia University..... 343

Stillman and McCall reaffirm, in reply, their views on traumatic occlusion as an etiological influence in the development of periodontoclasia, and restate their position on the relationship between systemic disorders and periodontoclasia. They remark that they "fail to see why the restoration of normal approximal contacts in the adult mouth is so perplexing a problem to a practising dentist," and that they approve of orthodontic treatment of periodontoclasia under suitable circumstances. They express "regret that the inference was drawn that correct instrumentation would entirely cure periodontal disease." What they intended to convey "had reference simply to the favorable reaction that does invariably follow correct removal of effete material from the root surface. To produce this result is only a part, but a very essential part, of periodontic treatment." They concede the validity of several of Albray's minor criticisms, but conclude by expressing "wonder why Dr. Albray finds such a difference between our theories and their practical application, since many dentists have applied these theories in practice and have found that they *do* 'work.'"

Stillman and McCall reiterate their statement that "periodontoclasia can be treated *and cured*" as they have claimed. See the last preceding and next succeeding abstracts; also pages xxv, lix and lxxii, in the section on proceedings, for comment on related subjects, in other connections, by Stillman and McCall.—(W. J. G.)

Progressive dentistry and stomatology. 9. A reply to a response to Albray's criticism of the review by Stillman and McCall, on the etiology, diagnosis, and treatment of periodontoclasia. By RAYMONDE A. ALBRAY..... 349

In his rejoinder Albray reaffirms his belief that traumatic occlusion is "a secondary or aggravating factor rather than an etiologic factor in the production of periodontoclasia." He disagrees with Stillman and McCall in the matter of effects of "a diet rich in vitamines;" he considers that, even if such diets have no *therapeutic* influence on periodontoclasia, deficiency of

vitamines may be a *causative* factor in the production of the disease. Albray feels that Stillman and McCall, in their discussion of his comment on their remarks regarding relationships between systemic disorders and periodontic disease, have failed to indicate (in response to his question) how they determined, as they stated in several connections, "that the periodontium was deranged *prior* to the occurrence of the systemic diseases" referred to.

Albray adheres to his position that "adult patients with sets of teeth in which the approximal contacts are normal, or could be restored to any near approach to normal, are rare," and that orthodontic treatment of periodontoclasia is unsuitable because orthodontic appliances always produce irritation and inflammation, and interfere with the maintenance of oral cleanliness. See the last two preceding abstracts.—(W. J. G.)

Experimental studies of the validity of advertised claims for products of public importance in relation to oral hygiene or dental therapeutics. 7. A study of some of the chemical qualities of Listerine Tooth-Paste. By MAXWELL KARSHAN, M.A., Instructor in Biological Chemistry, Schools of Medicine and Dentistry, Columbia University, New York City; and WILLIAM J. GIES..... 353

The authors find that Listerine Tooth-Paste is slightly acid in reaction, and mildly stimulative of the flow of saliva, as advertised. The stimulative effect on the flow of saliva appears to be due, in the main, to other influences than the *acidity*. The *acidity* seems to be too slight in degree, also, to explain the influence in preventing *accumulation* of hard tartar that is ascribed to it.—(W. J. G.)

The origin and evolution of the human dentition. Quotations from the preface of the author's book on this subject, recently published for the JOURNAL OF DENTAL RESEARCH. By WILLIAM K. GREGORY, Ph.D., Associate Professor of Vertebrate Palæontology, Columbia University; Associate in Palæontology, American Museum of Natural History, New York City..... 361

[Parts I–V of Gregory's review on this subject, which were presented in five successive quarterly issues of this JOURNAL (March 1920 to March 1921, inclusive—see page 87), have been revised by the author and, with a detailed index, have been published as a book of 548 pages, under conditions that will give the

proceeds of its sale to the Endowment Fund of the JOURNAL OF DENTAL RESEARCH.)

The parts of the preface that will be of special scientific interest to the readers of the JOURNAL are given on pages 361–366. Cope's discovery that the tritubercular type was ancestral to many if not all the higher types of molar teeth, "one of the most important generalizations ever made in mammalian comparative anatomy" (Osborn), and the "Cope-Osborn hypothesis of the origin of the tritubercular molar from the triconodont molar," are discussed from the standpoint of their relation to the whole of Gregory's review and the terminology involved. The principles in this relation, on which Gregory proceeded with his review, are briefly summarized and some of their consequences pointed out, including difficulties in nomenclature. Remarks on recent developments in the study of the "Piltdown problem" are included.

Corrections of, and addenda to, the five parts of the review (supplementing those given in the corresponding place under "errors and changes" in volume II of this JOURNAL) are presented on pages (44) and (46) of these introductory pages.—(W.J.G.)

Anesthesia of the middle superior dental nerve. By LEO STERN, D.D.S., Asistant Attending Oral Surgeon, Vanderbilt Clinic, School of Medicine, Columbia University, New York City.... 367

Stern describes the successful outcome of an effort to "amplify the generally accepted technique of local anesthesia of the oral cavity, to include a simplified method for securing anesthesia of the maxillary bicuspids by the conduction method." He discusses the evolution of related anesthetic procedures in general use and gives a history of his attempts to simplify the particular method under discussion. The technique he eventually adopted, which is "uncomplicated by difficulties in approach, and which obviates passage through either muscles or blood vessels," is described in detail, with accompanying illustrations. Results are tabulated, and general conclusions are summarized, at the end of the paper.—(W. J. G.)

Results of five years of dental prophylaxis for employees of the Metropolitan Life Insurance Company. By THADDEUS P. HYATT, D.D.S., Dental Director, Metropolitan Life Insurance Company, New York City..... 377

"During the past five years thousands of the employees of the Metropolitan Life Insurance Company have received two prophylactic treatments each year. Careful records have been made of mouth conditions." Hyatt presents summaries of the "data secured from 26,000 cleansing operations." The basis of his classifications and deductions is indicated in detail; and several tabulations present the gist of his very significant findings in the direction of cumulative improvement of dental and oral conditions. A plan for the further development of the research is detailed at the end of the paper.—(W. J. G.)

Present-day dental physiology. By FELIX P. CHILLINGWORTH, M.D., Professor of Physiology, Schools of Medicine and Dentistry, Tufts College, Boston, Massachusetts..... 383

Chillingworth presents the gist of six replies to a questionnaire (sent to the heads of departments of physiology in dental schools represented in the Dental Faculties Association of American Universities) "relative to the teaching of dental physiology." A copy of the questionnaire is given on the opening page. A "wide diversity of opinions pertaining to the teaching of dental physiology" is indicated. Quotations are presented, and the nature of the teaching in physiology at six dental schools is shown in two tabulations of data on (1) "the number of hours given to dental physiology," and on (2) "the nature of the courses that should precede dental physiology."—(W. J. G.)

Necessity for removal of all broken-off root tips. By J. A. HEIDBRINK, D.D.S., Minneapolis, Minn..... 389

Heidbrink "states his case" in the opening paragraph. He also refers to the difficulties in the way of direct extraction of teeth and to the mechanical impossibility of "removal without fracture," in many cases, "unless the way is prepared by careful dissection. . . . . Certainly there is much to be done," he says, "in the way of educating our patients and the general public regarding the high degree of skill required successfully and acceptably to remove teeth under all the varied adverse conditions."

"It is reported on reliable authority," according to Heidbrink, "that in one of our accredited dental colleges a recent senior class was taught, in both the surgical clinic and the lecture room, that, should root tips be broken off, it is not necessary to remove them —that they are absorbed with the process. Such teaching is

deplorable. . . . . The x-ray has revealed the fact that such tips and fragments of teeth, if left in the alveolus, usually remain there indefinitely and become infected, and sometimes suppurative, whether the tooth when extracted was vital or non-vital."

Heidbrink urges acceptance of the inevitability of occasional failures in extraction; avoidance of deception of the patient under such circumstances; education of the public in the difficulties attending extraction and in the consequences of incomplete removals; and insistence on thorough elimination of broken-off root tips whenever extraction results in their retention.—(W. J. G.)

Commercialized dental education. JOSEPH H. KAUFFMANN, D.D.S., Dental Department, Bronx Hospital and Dispensary, New York City..... 391

Kauffmann believes "the results of ten years of careful study and observation, in the field of dental education," warrant the statement that "the dental profession of today is menaced by a great danger, namely, commercialized education, which, imbedded in money greed, rotten with inefficiency, bankrupt in great teachers, steeped in self-appointed authorities, and lacking in examples of spiritual leadership, infects the hand that feeds it." The remedy? First, the "complete abolition of commercialized dental education;" second, "direct state control of . . . . the teaching of dentistry," since "even the philanthropically endowed institutions (such as the 'eastern type') are not conducive to the most wholesome interests of education." The dental schools in the "state-supported universities" in California, Illinois, Iowa, Michigan, and Minnesota are cited, by Kauffmann as "schools of the best standing."

Kauffmann suggests two additional reforms, namely, (a)" adoption of state laws which would make it legally impossible for any but graduates of 'class A' schools, after sufficient time for readjustment is allowed, to be admitted to practice;" and (b) "establishment of a single Federal Examining Board to take the place of the multitudinous state bodies, with interstate privileges to those who successfully meet its requirements."—(W. J. G.)

II. Papers in the Supplementary Section of the Volume

Proceedings of Dental and Stomatological Societies

The diagnosis of malocclusion with reference to early treatment. By A. LeRoy Johnson, D.M.D., Sc.D., Professor of Orthodontia, Dental School, Tufts College, Boston, Mass..... v

Johnson effectively emphasizes the biological as distinguished from the mechanical aspects of orthodontia. He presents a notable discussion of the basis and content of orthodontia from the biological standpoint. The scope of the author's review is shown in the contents-summary on page v.

"Fallacies in the assumption that orthodontia is a part of mechanical dentistry" are considered; and the conclusion that "orthodontia is based primarily on physiology, rather than solely on morphology," is defended persuasively. "Diagnosis is a problem of normal variation and, as such, is a question which can not be answered in the absolute." The review contains convincing and suggestive discussions of "the importance, in diagnosis, of the evidence relative to the evolution of the face and jaws as revealed in the race history of the species;" also of the "bearing of heredity on diagnosis," and of the significance "of the facts of embryology in an understanding of the etiology of malocclusion." The author's general practical conclusions are summarized on pp. xviii–xix. Johnson's vision of orthodontia is one of the signs of the times in the continuously rapid development of dentistry. [See the correction on page (49).]—(W. J. G.)

Symposium on diagnosis. By the six participants, and on the six subjects, designated below:

(I) Thoroughness in the examination of teeth for caries. By Wm. D. Tracy, D.D.S., New York City.....xxiii

(II) Early clinical evidences of disease in the gingiva and pericementum. By Paul R. Stillman, D.D.S., New York City..... xxv

(III) Recognition of factors that predispose to malocclusion. By Leuman M. Waugh, D.D.S., New York City..... xxxi

(IV) Pulp vitality: modern means of determining it. (A process by exclusion.) By Bertram B. Machat, D.D.S., Brooklyn, N. Y. xxxiv

(V) The value of the x-ray in the diagnosis of dental and maxillary diseases. By Robert H. Ivy, D.D.S., M.D., Philadelphia, Pa.....xlviii

(VI) Diagnosis of infections of the maxillary antrum. By HAROLD M. HAYS, M.D., New York City..... lii

Each of the parts in this notable symposium is, in effect, an abstract, the general nature of the contents of which is quite clearly indicated by the corresponding subject stated above. The sections by Drs. Stillman, Machat, and Ivy are illustrated. [See the corrections on pages (49) and (50).]—(W. J. G.)

The etiology of periodontoclasia. By JOHN OPPIE MCCALL, A.B., D.D.S., Buffalo, N. Y..... lix

The factors involved, the sequence of their consideration, and the full scope of the paper, which is in itself an abstract of McCall's views, may be seen at a glance in the table of contents on page lix, where the reader is directed to the pages on which particular themes are considered. (See the paper on page 73.)—(W. J. G.)

President's address; at the eighth annual meeting of the American Academy of Periodontology, in New York City on May 9, 1921. By PAUL R. STILLMAN, D.D.S., New York City..... lxxii

After alluding to some of the steps in the progress of the science of periodontology and in the development of the American Academy of Periodontology, Stillman said: "The trail blazed by the immortal pioneer, Riggs, has now become a highway, for the fundamentals which were laid down by him have, by the test of time and practice, been proven true. Experience and the development of our science have brought us all more knowledge, but there are few of us who have not lost our way at times and strayed into pretty paths that we believed were *short-cuts* to our destination. These *short-cuts* have led us into floundering swamps occasionally, like the Pilgrim of whom Bunyan has written." Then, in Bunyanic style, Stillman warns the members of the Academy "not to listen to the voice of the Swamp Angel: do not be led into the by-ways." Some of the short-cuts or by-paths "into which the Swamp Angel has attempted to entice us" are named, by Stillman, *Tartar Solvent, Autogenous Vaccines for Pyorrhea, Emetine, Mercitan, Vitamine.* He alludes to the results of McCall's study of the etiology of periodontoclasia, which are "recommended for review" (see page lix). Stillman welcomes "the advent of the dental hygienist" and believes "this Academy should become active in

shaping this phase in the development of our profession."—(W. J. G.)

Diet and efficiency. By MARTIN EDWARDS, M.D., Boston, Mass. lxxxi

Edwards discusses general facts pertaining to diet in its relation to the maintenance of health. Special emphasis is laid upon the importance of preventing excessive intestinal putrefaction and the consequent toxic effects (physical and mental) of the absorption of relatively large quantities of putrefactive products. Edwards favors a diet that is largely vegetarian in quality. He concludes that, although exceptions must be made for individual differences, in general the "diet for efficiency" is low in proportions of meats and high in proportions of vegetables, fruits, cereals, greens, and milk. [See the correction on page (50).]—(W. J. G.)

The occurrence, course, and prevention of chronic manganese poisoning. By CECIL K. DRINKER, M.D., Associate Professor of Applied Physiology, Harvard Medical School, Boston, Mass. lxxxiii

Drinker presents a full and masterly discussion of the subject. Manganese compounds are used in many industrial relationships and in the production of many common things, but known instances of manganese poisoning are few, possibly because "the symptoms are so bizarre that the physician unacquainted with the possibility of poisoning by manganese, and seeing a single isolated case, interprets the findings as an atypical instance of some more common type of *nervous* disease." The full scope of the paper may be seen at a glance in the table of contents on page lxxxiii, where the reader is referred to the pages on which the several sections are considered in detail.—(W. J. G.)

Research in dentistry. By WILLIAM J. GIES..... xciii

The author, aiming to stimulate the spirit of research among his auditors, stated that there is "certainly nothing mysterious or extraordinary" about research. He expressed the belief, addressing his auditors directly, "that each of you could begin tonight to proceed effectively with research in dentistry." He alluded to "some of the qualities, in addition to the prime virtues of honesty, courage, and common sense, that seem to be among the most important characteristics of successful investigators . . . . qualities . . . . shown to some degree by every normal, active, earnest, effective young man or woman in whom the spirit of unselfish aspiration is registered in zeal

for service." The "problem of income" was discussed in its practical relation to the expenditure of *time* in research. He urged that dentists can and should conduct research, and made practical suggestions bearing on such accomplishment. The "outlook" in dental research was briefly considered, and the relation of the JOURNAL OF DENTAL RESEARCH to the promotion of dental research was discussed.—(W. J. G.)

Preventive dentistry in the public school system. By M. M. BLUHM, D.D.S., New York City..... cv

Bluhm emphasizes the importance of preventive dentistry and argues earnestly in behalf, in this connection, of the "establishment of a dental clinic in every public school as a part of the school system, each clinic to be in charge of a dentist assisted by a dental hygienist." He gives in some detail the "method of procedure in the dental clinic of Public School no. 27, in the Bronx," based on five years of experience in that school.

"The advisability of giving *free* dental service has been questioned. I should like," says Bluhm, "to emphasize the fact that free dental service to school children in a school building does no more to pauperize the parents or the children than does free mental training, which all of us approve. *Every child is as much entitled to every possible public-health activity in its behalf as it is to a public-school education.*" Bluhm opposes "the system of centralized dental clinics," but advocates "the unit system—a clinic in each school building."—(W. J. G.)

The public-health problem. By E. BRIGGS RIBLET, D.D.S., Supervising Dentist, Bureau of Child Hygiene, Department of Health, New York City..... cx

"Understanding of the importance of oral hygiene has become almost universal." There is now a "great public demand for dental service." "The lack of public dental facilities in this City is notorious." "The Department of Health long since has appreciated the conditions in the dental field. It has faced the problem chiefly from the child's point of view. With the funds allotted to it by the City, the Department has established eight dental clinics for the exclusive use of school children. It also provides dental service in the Bureau of Preventable Diseases."

"The ideal way for the City to administer that part of the dental-health program that affects children would be to place a dental clinic in every school. To do this would necessitate an

initial expenditure of nearly two million dollars, an amount that is almost prohibitive. At present the City cannot be induced to expend such a sum for that purpose. . . . . Instead of trying to place the burden where it belongs, namely, on the private, semi-private or semi-public hospitals, dispensaries, clinics or such, all have tried to force it wholly on the City."

Dr. Riblet expressed a "fear that the day will never come" when the N. Y. Department of Health will receive "funds sufficient for the establishment of a dental clinic in every public school," because the public dental-health problem "includes the entire population and not the children only."—(W. J. G.)

The oral surgeon: his post-graduate training, his opportunities and his responsibilities. By WILLIAM C. FISHER, D.D.S., New York City. cxxv

Fisher discusses the present and prospective training of oral surgeons and orthodontists, especially from the comparative standpoint. He emphasizes the need for the organization of societies devoted to the advancement of oral surgery, and for the development of literature on oral surgery. He also states objections to, and consequences of, the payment and acceptance of commissions (divided fees).—(W. J. G.)

Soluble salts in saliva and urine. By WILLIAM J. REAM, D.M.D., Boston, Massachusetts cxxxi

A note on the predominant varieties of salts that may be crystallized from clear urine or salivary dialysates. Photomicrographs of crystals of six kinds of salts are presented. "The significance of these pictures is a matter for study and further investigation."—(W. J. G.)

Comparative abrasive qualities of five dentifrices. By HENRY J. CARNEY, D.M.D., Boston, Massachusetts cxxxiii

Under the given conditions of a test that is fully described and clearly illustrated, Kolynos was found to be least, and Pepsodent most, abrasive, in the following sequence of abrasiveness for the five dentifrices tested:

Kolynos < Bestol < Colgate's Paste < Pebeco < Pepsodent

The author presents, with his results, quotations from letters written by the proprietors of the dentifrices under examination.—(W. J. G.)

A résumé of the findings of research on the evolution of dental alloys and amalgam technique. By HARRY JEROME BAKER, Assistant Professor of Operative Dentistry, Dental School, Tufts College, Boston, Massachusetts.....cxxxvii

After referring to earlier historical aspects of the subject, Baker discusses "modern points of view" pertaining to the composition, physical properties, production, and manipulation of dental alloys, and then gives detailed attention to "results of recent researches," the most important of which "have been conducted by Arthur W. Gray at the L. D. Caulk Laboratories, Milford, Delaware, and by the United States Bureau of Standards, Washington, D. C. These investigations have been conducted along scientific lines with the aid of modern instruments and have yielded much interesting data. They agree in the main, so far as their conclusions have been published."

Baker discusses particularly the new results that bear on influence of (a) variations in the mercury-alloy ratio, of the (b) size of the alloy particles, of (c) trituration time, and of (d) packing pressure. At the end of his paper, Baker summarizes ten "practical applications from the standpoint of the operative procedure."—(W. J. G.)

A brief history of periodontology. By ARTHUR H. MERRITT, D.D.S., New York City.....cxlix

Merritt presents successively a general historical introduction, and carefully detailed discussions of the "work and career of John M. Riggs," of the "history of the term pyorrhea alveolaris," of an "era of discordant views and efforts," and of "recent developments" including the "organization and development of the American Academy of Periodontology." A bibliography of forty-four references is appended.—(W. J. G.)

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This register, with the additions to be made to it—a cumulative honor roll in dentistry—will be republished here annually as a recurrent testimonial to the generosity of those who, by their gifts to this Endowment Fund, will have established a permanent foundation for the unlimited growth and increasing usefulness of this Journal as an effective agent, in the public service, for the promotion of science and art, and the advancement of dentistry and stomatology.

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Total amount of the fund.....	5 831.75
Expenditures from the fund.....	*None*
Total amount of the fund held in U. S. securities at rates of interest ranging from 3.5 per cent to 6 per cent.....	5,500.00

WILLIAM J. GIES.

Biochemical Laboratory of Columbia University,
Schools of Medicine and Dentistry,
437 West 59th Street, New York City,
December 15, 1921.

REVIEWS OF BOOKS RECEIVED FOR THE LIBRARY OF THE JOURNAL OF DENTAL RESEARCH

THE JOURNAL OF DENTAL RESEARCH promptly acknowledges in the "contents" section of each number, the receipt of new publications presented to it. Books selected from those received are reviewed in the "contents" section and the reviews are reprinted here. Reviews are matter-of-fact statements of the nature and contents of the publications referred to and are *intended solely to guide possible purchasers*. The suggestions or expectations of authors or donors of volumes will be disregarded, if and when they appear to be incompatible with our convictions regarding the interests of our readers.

Oral anesthesia. Local anesthesia in the oral cavity. Technique and practical application in the different branches of dentistry. By KURT H. THOMA, D.M.D., Assistant Professor of Oral Pathology, and Member of the Research Department, Harvard University Dental School; Instructor in Dental Anatomy, Harvard University Medical School; Oral Surgeon, Robert Breck Brigham Hospital, Boston, Mass. (*Second edition, revised.*) 1920; pp. 185; $6\frac{5}{8} \times 4\frac{1}{8}$; $4.50. M. C. Cherry, Boston, Mass.

This is a most excellent treatise and the subject matter is presented in a thoroughly attractive way. Thoma's drawings and charts (pp. 140–143, inclusive), which show the points of injection as well as the quantity of anesthetic to be used, are excellent guides to men who are taking up this particular work. They are also splendid as a method of impressing these points on the mind of the operator who uses oral anesthesia in his daily practice.

There are only two minor criticisms which, I think, should be made of his work. One is he uses the capital letters "O. T." in connection with the descriptive readings at the bottom of some of his illustrations and does not make an explanation of what these two letters mean. Taking up this matter with him by correspondence, I found that the letters stand for "Old Term." However, it is not so indicated in the book and, unless the reader gets this knowledge from some other source, he is likely to be somewhat confused. Again, I note that, in referring to the third molar, he frequently speaks of it as the "wisdom tooth." Although this nomenclature is quite ancient, he does not put the letters "O. T." in connection with it. In describing the third molars, it would have been better to use the words "mandibular third molar" and "maxillary third molar."

On the whole, the book is quite a valuable addition to our literature on the subject of oral anesthesia, and it should be in the library of every dentist.—*Thomas P. Hinman, Atlanta-Southern Dental College, Atlanta, Ga.*

American year-book of anesthesia and analgesia for 1917 and 1918. By F. H. McMechan, A.M., M.D., Editor. 1921; pp. 483 (double column); 8¼ x 6; $10.00. Surgery Publishing Company, New York City.

The first thing seen on opening this large, scarlet-bound volume is an advertisement; and the last is a whole series of advertisements. It may indeed be true, as the editor says in the preface, that the co-operation and support of advertisers has been made necessary by the greatly increased cost of producing the year-book; but it seems unnecessary for the editor of a volume as important as the year-book purports to be to bespeak the reader's "good-will and interested attention for the pertinent products in the advertising section."

There are many features of the book that can be commended. England, France, Canada, and the United States have been drawn upon for contributors, so that its scope is indeed international. Extended reports of almost every worth-while advance in anesthesia and analgesia are presented. The papers dealing with the same or related subjects are happily grouped together. There are seven admirable articles dealing with complicating factors of anesthesia. In the section entitled anesthesia and acidosis are papers by such authorities as William de B. MacNider and Yandell Henderson. Under the rather ponderous title of "pharmaco-physio-pathology of general anesthetics" appear discussions of the "physio-pathology of ethyl chlorid," the "Cotton-process ether and ether analgesia," "the pharmacological action of nitrous oxide," "the nature of nitrous oxide and ether anesthesia," etc. Rather more than one-seventh of the volume is devoted to anesthesia at the front and in war surgery. Local anesthetics are considered with the fullness they deserve: there are papers dealing with their comparative values, and the pharmacology of two of the newer local anesthetics is described. There are also groups of papers dealing with local anesthetics in the surgical specialties, and in dentistry and oral surgery. Sacral and spinal anesthesia are not forgotten. A valuable feature of the volume is an index of the current literature of anesthesia for 1917–1918.

Although the exigencies and demands of the world war delayed for three years the publication of this second volume of the American Year-Book of Anesthesia and Analgesia, it will appeal to all those members of medical and allied professions who in any manner come into contact with the science and practice of anesthesia and analgesia.—*C. C. Lieb, Schools of Medicine and Dentistry, Columbia University, New York City.*

The microscopic anatomy of the teeth. By J. Howard Mummery, D.Sc., M.R.C.S., L.D.S., Eng. *First edition,* 382 pages, 243 illustrations. London, England: Henry Frowde, Oxford University Press; Hodder & Stoughton, Warwick Sq., E. C., 1919.

The author of this valuable monograph is well-known through his many publications in both British and American scientific, medical and dental journals, among which are articles on the enamel prisms;

the structure, development and calcification of enamel and dentine; the structure of the dental follicle and its relations to pathological conditions; the pathology of pink spots on teeth; and the morbid histology of the teeth. He has now published in book form the results of his investigations, bringing up to date our knowledge of the histology of the teeth.

The author has avoided lengthy discussions of obsolete views, in order to give the student a clear understanding of the present state of knowledge of the different theories. This should make the volume interesting and desirable for the practising dentist, by giving him, in convenient form, all the modern theories of the microscopic structure with which he is dealing. "In presenting the results of my own investigations," the author says in the preface, "I hope I have adequately acknowledged the work of others on the same subject." This he certainly has accomplished, as evidenced by the many references at the end of each chapter, including practically all the modern publications of research work in English and foreign literature.

The principal subject is well introduced by a phylogenetic description of the development of the masticating apparatus and the teeth themselves.

The first chapter treats of the development of the teeth in mammalia. In this chapter the ontogenetic development of the teeth is considered, special attention being paid to the evolution of the human molar.

Chapters II and III deal with the enamel. The question of the content of organic matter in the enamel, which is both a modern topic and one of practical value, is considered from the chemical and microscopic aspects. The statement of Leon Williams that the "enamel is an entirely inorganic tissue," and which our author thinks should be modified, has since been repudiated by Williams himself in a discussion of a paper by Dr. C. S. Bodecker. Drs. Bodecker and Williams have shown slides of stained enamel, in which they demonstrated the existence of organic structures.

In a further chapter the dental pulp is considered. Its blood vessels, lymphatics and nerves receive proper attention. A discussion, in this part, of nutrition and of calcium metabolism might have added a great deal of interest. It is not mentioned in this book, although it is one of the most important topics of the day. The author's work on nerve endings and innervation of the dentine, as well as Deppendorf's excellent work on the same subject, should be read by every practising dentist. Brilliant illustrations, of specially stained specimens, give a clear conception of this important discovery.

The next chapter is devoted to dentine, its development and calcification. Hanazawa's and Romer's conception of the odontoblastic process as a tubular structure is modified by the author. The word "tube" implies a hollow structure with a terminal opening, and in this instance, as Mummery states in the summary, we are dealing simply with a process which is an elongation of the cell, made up of cytoplasm with a slightly denser, stainable outer layer. He also believes that the

interstice exists between the process and the wall of the dentinal tubule, along which fluids can pass. He does not, however, express any opinion on the function, or relation to metabolism, of this fluid.

The sixth part deals with the cementum. The author states that haversian canals are occasionally found, but are of rare occurrence. He also describes vascular canals in the apical part of the tooth (illustrated in *fig. 192*). Doubtless they are accessory foramina. In America we prefer the name cementoblast to osteoblast, for the cement-forming cell.

Chapter VII is entitled "the periodontal membrane." This chapter does not come up to the excellent standard of the previous parts. A short paragraph is devoted to the histology of the gum. The statement that "simple mucous glands are abundantly found in the gum tissue," with no further explanation, is abrupt to say the least. The rest of the oral mucous membrane is not mentioned.

Under the title of "the tooth follicle and its connexions," the author devotes Chapter VIII to a description of Hertwig's sheath and the epithelial debris of Malassaz, which are illustrated by beautiful photomicrographs.

Chapter IX discusses Nasmyth's membrane and the eruption of the teeth. Chapter X describes the different modes of attachment of the teeth in animals and man, while the last chapter is devoted to a brief description of "horny teeth."

In conclusion, the book can be highly recommended as a modern treatise on the microscopic anatomy of the tooth tissues proper. Most of the many illustrations have been prepared and photographed by the author and some are exceptionally fine. Speaking, however, from the standpoint of a teacher of dental histology, which includes that of the entire oral cavity, it is to be regretted that the investing tissues of the teeth, the mucous membrane, the maxillary bones, and the salivary and mucous glands, have not received the careful attention that is generally exhibited in other relations throughout the book.—*Kurt H. Thoma, Harvard University Dental School, Boston, Massachusetts.*

ERRORS AND CHANGES

A copy of at least one printer's (galley) proof is presented to each author of a paper published in this JOURNAL. Occasionally, typewritten copies are also submitted to authors, for verifications of editorial revisions, before the manuscripts are forwarded to the printer. Frequently, besides, a second (paged) printer's proof is sent to authors, to afford further opportunity for the detection and correction of mistakes.

Shortly after the publication of the successive issues of this JOURNAL, we send to each author concerned a copy of his paper, or discussion, and of the corresponding "contents" abstract (taken from a finished copy of the number), with the request that a careful examination be made for the detection and formal correction of any errors that might have appeared. Special effort is made, by the editorial and publication offices, to prevent the occurrence of typographical and other errors but, of course, occasional oversights are inevitable. We desire, however, publicly and formally to correct errors when they occur, and to afford authors opportunity promptly to record revisions, in order that this JOURNAL may attain the highest possible realization of the ideal of perfect accuracy in every statement published on its pages.

We summarize, below, the only corrections and revisions that have been reported to us by the authors of the contents of Vol. II and nos. 1, 2 and 3 of this volume.[1]

VOLUME II[2]

Abstract by William J. Gies

Page (20); general section. Abstract of the paper by Henrici and Hartzell: Hartzell's title should have been given as *Research Professor of Mouth Infection* instead of "Assistant Professor of Bacteriology."

[1] Corrections pertaining to no. 4 of this volume, if any should be reported, will be published at this place in volume IV.

[2] Corrections on nos. 1, 2 and 3 are additional to those noted in the corresponding place in volume II.

ERRORS AND CHANGES

Book review by E. H. Raymond

Page (34); general section, sixteenth line (bottom). "Erysipelatous" should be *erysipelatis*.

Papers by William K. Gregory

Page 105. Fourth line (top): "singel" should be *single*. Fifteenth line (top): after "intercalating," insert (*Plate 1*). Fourth line (bottom): insert (*fig. 11*).

Page 106; *fig. 11*. In the italicized legend, the letter "D" after B, and C, should be followed in each case by a period instead of a comma, to represent *Diademodon*.

Page 111. The foot-note numeral should follow *squamosal* in the tenth line (top).

Page 113; first line. The "two roots" referred to, it should be noted, are not yet entirely separated.

Page 114; ninth line (bottom). "1902" should be *1903*.

Page 116; *fig. 17*. At the head of the second legend, "2c" should be *2*.

Page 129; *fig. 21*. Legend 9: "A, the same" should read *A, the same, X 3*. Legend 10: after "ramus" insert *X 1*; and between the semicolon and "X 3," insert *A, the same*.

Page 135; *fig. 25*, legend c. "P. t nuirostris" should be *P. tenuirostris*.

Page 136; eighth line (top). "Trituberculate" should be *Trituberculata*.

Page 138; third line (bottom). "Amphiteriidæ" should be *Amphitheriidæ*.

Page 141; *fig. 29*. After "A, the same," the magnification sign should be *X 4* instead of "X 3."

Page 142. Parts *c* and *d* of *fig. 30* show *right* instead of "left" lower molars.

Page 143; *fig. 31*. At the end of the legend add: *These molars consist only of the primary trigon. See page 144.*

Page 144. Under the legend insert: *The upper molar crowns comprise only the primary trigon.*

Page 147; tenth line (bottom). "Diademodon-like" should be *Peralestes-like.*

Page 148; seventh line (top). "Chrysochloris" should be *Notoryctes*.

Page 155; second line (top). Insert *is* between "and" and "probably."

Page 158; *fig. 39*. "Compare with Plate II" should read *compare with plates 2 and 4.* At the end of section 1, insert *Cf. fig. 47 (1)*; after section 2, *Cf. fig. 47 (2)*; after section 3, *Cf. fig. 47 (3)*.

Page 159; at the end. Insert (*Plate 3*).

Page 162; third line above the central heading. After "cingulum" insert (*Plate 3*).

Page 163; second line (top). Insert (*Plate 4*) between "phalangers" and "in."

Page 234; seventh line under "origin of the primates." "Macroscelidæ" should be *Macroscelididæ*.

Page 246. Fifth line (top): "apex" should be *cusp*. Eighth line (top): "molars" should be *premolars*.

Page 250; last line. Parenthetical reference to *fig. 63* was omitted. (In this correction, on page (44) under "errors and changes" in vol. II, "*fig. 56*" was mistakenly specified instead of *fig. 63*.)

Page 270; seventeenth line (bottom). "Macroscelidæ" should be *Macroscelididæ*.

Page 271; eleventh line (top). "Fourth upper molar" should read *fourth upper premolar*.

Page 359; sixth line (top). "*Figs. 79–91*" should read *figs. 79 and 91*.

Page 377; second line (top). "1884" should be *1885*, and "1903" should be *1902*.

Page 408. "Amer. Mus. no. 11,689," in each of legends 1 and 3 under *fig. 149*, should be *Amer. Mus. no. 11,982*.

Page 411; third line (top). "1915" should be *1917*.

Page 621; fifth line (bottom). "Elongation (*fig. 229*)" should be *elongation* (*fig. 234*).

Page 628; seventh line (top). After "mandible" insert (*figs. 230–232*).

Page 640. "Hylobales" should be *Hylobates*.

Page 653; seventh line (bottom). "Anthropoids-man" should be *anthropoid-man*.

Page 659; *fig. 248*, legend B. "Haeckli" should be *haeckeli*.

Page 688; supplementary comment on the "Piltdown problem." While Part V was in press, and since that time, Professor Osborn, Dr. Matthew and Professor J. H. McGregor have each examined the original Piltdown remains, and the later ones described (1917) by Smith Woodward. They have all come to the conclusion that the more recently discovered lower molar tooth is much like the original type, and that it lends strong evidence in favor of Smith Woodward's conclusion that the ape-like lower jaw belongs with the man-like skull. They also indorse Smith Woodward's conclusion that the ape-like canine is a lower and not an upper one, and the same opinion is held by Dr. Milo Hellman, whose intimate knowledge of the occlusal surfaces of teeth lends weight to his opinion.

Page 704. For directly comparative purposes, *fig. 278* is upside down.

ERRORS AND CHANGES

Paper by Arthur T. Henrici and Thomas B. Hartzell

Pages 537–550; authors' general comment. "I note that we have used the word cuspid and canine interchangeably. The word cuspid should have been used all through the protocols."—T. B. H.

Paper by Josef Novitzky

Page 586; third line of middle paragraph. Change "cannot afford evidence" to *must not be taken as evidence.*

VOLUME III, NOS. 1, 2, and 3[3]

Paper by E. F. Robb, Grace Medes, J. F. McClendon, Margaret Graham, and I. J. Murphy.

Pages 53 and 54 were omitted by accident from the March number when the copies were bound. These pages were appended to the June number. (See the announcement on page 299.)

Paper by Paul R. Stillman and John Oppie McCall

Page 75; third line (top). "Facts" should be *factors.*

Page 77; fifteenth line (bottom). "Microscopic" should be *macroscopic.*

Page 83. Sixth line (top): "opicoectomy" should be *apicoectomy.* Seventeenth line (bottom): "lactic" should be *luetic.*

Paper by William K. Gregory

Page 87; section II. "Heidelbergesnis" should be *heidelbergensis.*

Page 99; *fig. 302.* "Tasmanian man" should read *Tasmanian aboriginal woman.*

Page 104; second paragraph, seventh line (top). "Ancestors for" should be *ancestors of.*

Page 110; foot note, first line. "Fourtan" should be *Fourtau.*

Page 111; eleventh line (top). "Pliocene" should be *Miocene.*

Page 123. Dr. Milo Hellman has written as follows to Dr. Gregory, in comment on section "(9)": The last part of the sentence referring to molar occulsion is true only of the third molars. In the first and second molars the disto-lingual slopes of the disto-buccal cusps of the upper molars come into occlusal relation with the mesio-buccal slopes of the mesio-buccal cusps of the lower molars distal to them. It would therefore appear

[3] See vol. IV for corrections on no. 4 of vol. III.

that the molar occlusion in man has not entirely lost its primitive character even on the buccal side. In instances where this occlusal relationship is disturbed, it should more properly be considered either as an individual variation or as an anomalous manifestation. (Disto-buccal cusp = metacone. Mesio-buccal cusp of lower molars = protoconid.)

Pages 131–138; plate 15, *figs. 324–329*, inclusive. Add *X 3/2*.

Page 177; ninth line (top). "Complied" should be *compiled*.

Page 180; eleventh line (bottom.) Omit "to black."

Page 189; fourth line (bottom). Insert (after Grant) *or to the Indonesians* (*L. R. Sullivan*).

Page 193; fifth line (top). Omit "aquiline."

Page 196; last line. "Nose prominent" should read *nose wide to prominent*.

Page 222; bibliography. Add: Hrdlicka, A. 1921 Further studies of tooth morphology, *Amer. Journ. Phys. Anthrop.*, iv, pp. 141–176.

Page 224; bibliography. Add: Matthew, W. D. 1910 On the skull of Apternodus and the skeleton of a new artiodactyl. *Bull. Amer. Mus. Nat. Hist.*, xxviii, pp. 33–36. (Evolution of zalambdodont molars, order of cusp development.)

Page 228; bibliography. Add: Wortman, J. L. 1921 Evolution of molar cusps in mammals. *Amer. Journ. Phys. Anthrop.*, iv, pp. 177–188.

Paper by J. F. McClendon

Corrections in the lists of names of plants (*pp. 282–292*).

LIST NO. 1

Original	*Correction*[1]
Acanthocheton	Acanthochiton
Acornus	Acorus
Agaricus campester	Agaricus campestris
Agrostis perennaus	Agrostis perennans
Amelanchia	Amelanchier
Amorpha canensens	Amorpha canescens
Aphlopappus	Aplopappus
Aquillegia	Aquilegia
Astragalus . . . . diphysus	Astragalus . . . diphacus

[1] Justice to the printer requires the statement that these corrections are necessitated by many errors in the author's manuscript, which were not detected by the author when the printer's proofs were submitted to him but which have been noted since the publication of the paper.—(W. J. G.)

LIST NO. 1 (continued)

Original	*Correction*
Calandrinia cawlescens	Calandrinia caulescens
Calliproa	Calliproxa
Carcum	Carum
Castanopsis chrysophilla	Castanopsis chrysophylla
Caulophyllium	Caulophyllum
Chrysopsis villosus	Chrysopsis villosa
Clematis lingusticifolia	Clematis ligusticifolia
Cnicus drummondi	Cnicus drummondii
Coprinus . . . . a tramentarius	Coprinus . . . . atramentarius
Cripis	Crepis
Cycloloma atriphicifolium	Cycloloma atriplicifolium
Cymoterus	Cymopterus
Dithyraea wislizeni	Dithyrea wislizenii
Echeveris	Echeveria
Elaegnus	Elaeagnus
Escholtzia	Eschscholtzia
Euonymus atropurpurea	Euonymus atropurpureus
Euphorbia serphyllifolia	Euphorbia serpyllifolia
Euretia	Eurotia
Gaylusacia	Gaylussacia
Gutierrezia euthamniae	Gutierrezia euthamiae
Gymnolemia	Gymnolomia
Hedeoma . . . . drummundii	Hedeoma . . . . drummondii
Hesperoscordium	Hesperoscordum
Juglans . . . . cinera	Juglans . . . . cinerea
Kryntzkia	Krynitzkia
Laciniaria	Lacinaria
Lepargyrea	Lepargyraea
Lithospermum . . . . canencens	Lithospermum . . . . canescens
Mitchella repeus	Mitchella repens
Muscadinia . . . . rotindifolia	Muscadinia . . . . rotundifolia
Pentstemum	Pentstemon
Peucidanum	Peucedanum
Philibertia beterophylla	Philibertia heterophylla
Phorandendron	Phoradendron

LIST NO. 1 (continued)

Original	*Correction*
Photinea	Photinia
Promus	Bromus
Prunus demissa	Prunus (= Padus) demissa
Pseudotseuga douglassii	Pseudotsuga douglasii
Ramunculus	Ranunculus
Ratibida columaris	Ratibida columnaris
Rhamnus purschiana	Rhamnus purshiana
Rosa . . . . nutcana	Rosa . . . . nutkana
Rubus . . . . stragosus	Rubus . . . . strigosus
Sheperdia	Shepherdia
Solanum . . . . elaegnifolium	Solanum . . . . elaeagnifolium
Trifolium . . . . microsephalum	Trifolium . . . . microcephalum
Triticum vulvage	Triticum vulgare
Vitis . . . . cordifolai	Vitis . . . . cordifolia
Washingtonia longistaylis	Washingtonia longistylis
Yucca . . . . treculeans	Yucca . . . . treculeana

LIST NO. 2

Arachis hypognea	Arachis hypogea
Cerica	Carica
Chenopodium quinoii	Chenopodium quinoa
Cocus	Cocos
Cucumis angurica	Cucumis anguria
Lycopersicon lycopersicum	Lycopersicon lycopersicon
Psidium guayaba	Psidium guayava

Paper by A. LeRoy Johnson

Page xix; fifth line above "references to literature." "Interfere with normal growth processes" should be changed to *interfere with, or indicate perversion of, normal growth processes.*

Paper by Bertram B. Machat

Page xxxviii; legend for *fig. 1 A*. "Intra- and extradental" should be changed to *intra-oral film of.*

Page xxxix; end of first paragraph. "Refractive" should be *refractory.*

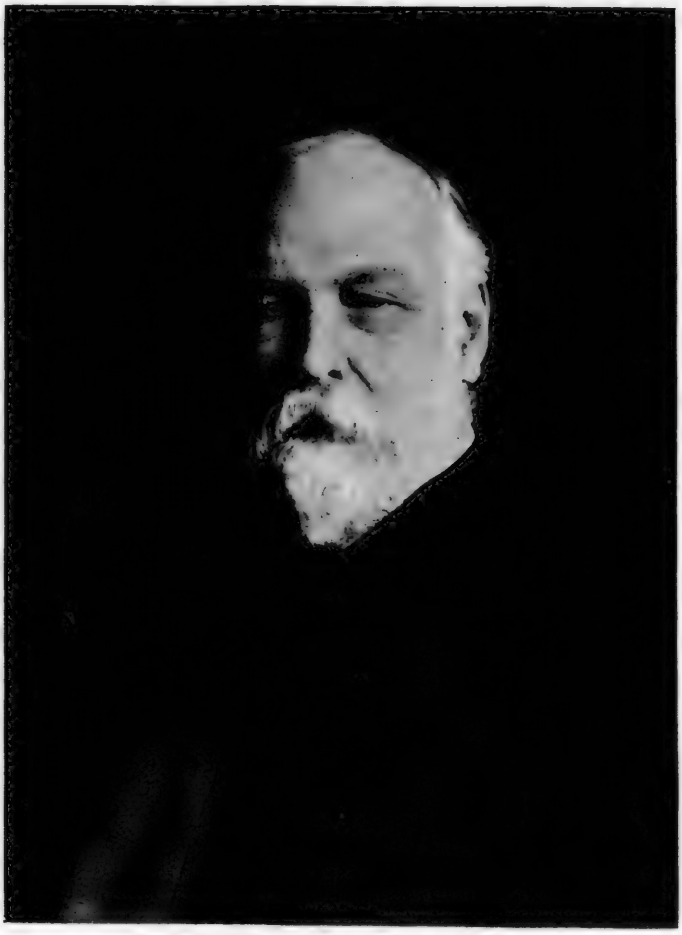
ERRORS AND CHANGES

Paper by Robert H. Ivy

Page li; third line above paragraph on odontomas. "I have discovered" should be changed to *the x-ray may discover.*

Paper by Martin Edwards

Page lxxxi; concluding line. "Milk, fruits and vegetables" should be changed to *vegetables, fruits, cereals, greens, and milk.*



P. P. Andrews

ROBERT ROBBIN ANDREWS

An Appreciation

GEORGE A. BATES

Tufts College Dental School, Boston, Massachusetts

Dr. Robert Robbin Andrews, a veteran of the Civil War and one of the best known dental surgeons of Massachusetts, died at his home in Waban, Mass., on Wednesday, January 26, 1921. His death was caused by heart trouble.

Dr. Andrews was born in Boston seventy-six years ago. He was educated in the public schools of Boston and was a graduate of Boston Dental College. He entered the Civil War and served two years, having been promoted from the rank of private to lieutenant. He practised his profession of dentistry for many years in the city of Cambridge, Mass. He was professor of histology in Boston Dental College. When this institution was merged with Tufts, and became Tufts College Dental School, he was made a member of the Board of Trustees of Tufts College, which position he held until his death.

In 1892 he received the honorary degree of A.M. from Dartmouth College for distinguished service in the dental profession. In 1911 he was awarded the Jarvie gold medal by the New York State Dental Society "for distinguished service in the science and art of dentistry." He had been president of several of the dental societies, including the Massachusetts Dental Society and the American Academy of Dental Science. He was a member of the Royal Microscopical Society and several other foreign microscopical societies; and was the author of many publications on subjects related to his profession.

He is survived by his wife, Mary LeSeur Andrews, and four children: Dr. Robert E. Andrews of Springfield, Mass.; and Dr. Horatio L. Andrews, Mrs. A. L. Richards and Mrs. Bruce Wyman, of Waban, Mass.

M. H.

To one who was privileged to know Dr. Andrews, the influence of his inspiriting personality can never wane. His genial smile and his cordial greeting were characteristics which endeared him to a host of friends.

The work that he accomplished in the profession of dentistry is epoch making. He was a born researcher; and at a time when the only literature on his favorite subject of tooth development was John Tomes' Dental Anatomy, in which the profession had for years been led astray by the erroneous statements concerning enamel development, and by the fantastic perpetration of Le Gros and Magitot—and when there were no precedents—he attacked the problem of tooth development.

He improvised his own microtome, cut and photographed his own sections under the most adverse conditions, and gave the profession the very first suggestion of the true story of the embryology of enamel. He demonstrated for the first time the existence of calcospherite and made clear the true relation of the parts of the enamel organ, thus making possible a knowledge of the involved structures which have been the basis of all subsequent studies in this most difficult subject. (See his review in this relation: JOURNAL OF DENTAL RESEARCH, 1919, i, p. 353.)

When it is considered that he devised a method of photomicrography by which he was enabled to produce photographs, through a 1/12 oil-immersion objective, of the minute details of the structures on which he worked, the extremely difficult conditions under which he accomplished his surprising results may be more fully appreciated.

It is to be understood that this work was done at a time when the appliances that are at the hand of the present-day worker had not been invented, and all the results were achieved with improvised apparatus which, in less skillful hands, must have proved inadequate. I have heard him tell many times of the hours spent, after a hard day's work at the dental chair, in this eye-and-brain taxing study.

It is to such pioneers as Dr. Andrews that we owe our best knowledge—men without hope of reward, with only one purpose in mind; and whose absorbing ambition it is to push the horizon back a little farther, to enlarge the world's wisdom and to blaze the way for those who are to come after them, that groping hands and faltering

footsteps might be a little less uncertain. These are the men who have climbed the Mountain and set the signal of success a little higher, so that those in the Valley might mark the way and not fail therein. Malpighi, Leeuwenhoek, Wolff, Hunter, Kölliker, Tomes—these are among the honored names emblazoned on the tablets of the Hall of Fame; and on one tablet, not the least among them, we would write the name of Andrews. We do this with fitting pride for he belongs to us. His well-known form and kindly face are familiar as he went in and out among us; and we are glad to claim him and the honor he has achieved as a part of the heritage that has fallen to us out of his fruitful life and activities.

His interest in the welfare of the profession never faltered. Only a few weeks before his death a company of men gathered at the Harvard University Club in Boston for the purpose of establishing an association for dental research and Dr. Andrews was among them.[1] He was eager to express his interested sympathy with the object of the gathering and his inspiring words were among the most helpful and best remembered of the occasion.

A student, an artist, a soldier, a scientist: he gave the world his best for learning, for patriotism, for the advancement of his beloved profession—what could he do more? He has filled a large place in the lives and affections of his fellowmen. It is the end of a good life and we lay the laurel wreath of victory on his grave and feel, as we turn away to the affairs of life, that we are stronger and better because we have known him.

[1] The author refers to the second meeting of the International Association for Dental Research, of which Dr. Andrews was one of the founders.—(*Ed.*)

FOOD ACCESSORY FACTORS IN RELATION TO THE TEETH

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III. Dental and osseous decalcification and recalcification, experimentally induced by modifications of diet 8
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I. INTRODUCTION

The effect upon the teeth and gums, of diets deficient in vitamines, has been noted by many writers. McCollum and Pitz (3) and Cohen and Mendel (1) have observed, in guinea pigs, loosening of the teeth and bleeding or congested gums associated with vitamine-deficient diet. Mrs. Mellanby (5) produced irregular teeth in pups by rachitic feeding. Zilva and Wells (8) examined histologically the teeth of guinea pigs fed on a scorbutic diet, and reported degenerate changes both in the teeth and in their pulps.

II. THE FERMENTATION THEORY OF DENTAL CARIES

The most generally accepted theory of dental caries is that of Miller. Miller (6) held that the fermentation of carbohydrates, with the formation of lactic acid, was the cause of tooth decay. He based his ideas upon the results of the following experiment: Teeth were placed in a fermenting mixture of bread and saliva, which he renewed from time to time that it might not become alkaline. After three months he obtained effects upon some of the teeth which, he states, could not be distinguished macroscopically or microscopically from true decay. By the method of zinc crystallization he demonstrated the

presence of lactic acid in the fermenting mixture. He felt that he had proved his theory. Histologically Miller studied only the carious mass. He ignored the condition of the tooth substance immediately in advance of the decay. Bacteriologically his work was limited and he found no specific organism which he could regard as the etiological factor in caries.

We repeated and extended his experiment. We placed the teeth in fermenting aqueous mixtures of dextrose, maltose, lactose and saccharose, of dextrin and white flour, and of bread. In some of the tubes we used saliva from individuals that had extensive tooth decay, in others saliva from cases free from decay, and in others saliva from unselected cases. After six months some of the teeth showed an etched appearance, some a decalcified effect, and in others no change was discernible. In general the effects resembled those on teeth subjected to the action of a weak decalcifying agent. The most pronounced thing brought out was the great difference *in structure* of the various teeth. Miller himself noticed this. He wonders why the teeth of pigs, which feed largely upon the fermentable foods, are free from decay.

If Miller's theory is sound it should be an easy matter to produce tooth decay in animals by fermentation. We have fed guinea pigs upon diets containing large amounts of the sugars and starches. This diet was continued for from six months to a year. The sugars were readily eaten and adhered constantly to the tooth surfaces. The flora of the mouth became aciduric in character, but no effect could be detected in any of the teeth. We fed for three to four months microörganisms isolated from caries: B. acidophilus, B. "X," B. ramosus (2). The growths were constantly present in the mouths of the animals. No effect upon the teeth could be found. All the animals appeared to be in good condition at the end of six months and even of a year.

III. DENTAL AND OSSEOUS DECALCIFICATION AND RECALCIFICATION EXPERIMENTALLY INDUCED BY MODIFICATIONS OF DIET

We have, however, obtained rather extensive effects in the teeth, in the alveolar process, and in the jaws themselves, by feeding diets deficient in each of the three known kinds of vitamines. The effects

are not confined to the teeth and their adjacent structures, but are to be seen to a certain extent in the skull-bones and in other bones of the body.

The majority of our animals, chiefly guinea pigs, were fed a simple diet of rolled oats and fat-free milk.[1] Each received about 25 cc. of the milk daily, and all the rolled oats it would eat, with a very small piece of carrot and a small leaf of lettuce every other day or every third day. The animals were carefully watched, and when difficulty in the use of their legs was manifest, or difficulty in eating observed, the amount of green food was increased. This addition was necessary in order to prevent death, which at this late stage may ensue suddenly. Our object was to produce a chronic condition in which calcium would be slowly removed from the bony structures. Thus our experiments extended over periods of from three months to a year.

When the development of the symptoms was so rapid that the animals were unable to eat green foods, we fed them orange juice from a medicine dropper, which they took with great avidity. The beneficial effects of the orange juice were quickly evident; the animals were soon able to eat grated carrot, and later thin slices of carrot and lettuce. On the latter diet, combined with whole milk, they soon regained weight and appeared nearly normal. They were then again placed on a diet of rolled oats and fat-free milk, the green food being reduced to the lowest possible quantity. In some cases McCollum's salt mixture no. 185 (4), or Osborne and Mendel's (7) salt mixture, or calcium lactate, was added to the diet, although the milk presumably furnished a sufficient amount of inorganic constituents. Agar-agar was also added to the diet, in some cases, for its beneficial mechanical effect upon conditions in the intestinal tract. By the use of such diets, we could keep the animals, closely under observation, for a protracted period in any state desired.

In this manner we produced very marked loosening of the teeth, together with extensive absorption of the alveolar process. If this effect was brought about slowly, and continued for about four months, it resembled the alveolar absorption of senility; if brought about with more rapidity and severity, the appearance was more like that of carious bone. The condition closely simulated the various forms of

[1] Walker-Gordon fat-free milk and fat-free "Klim" were used.

pyorrhea alveolaris. The gums bled, and in some instances a copious flow of pus occurred.

Under these conditions, the teeth, particularly in *young* guinea pigs, are regularly decalcified. A distinct bending of the teeth may be observed—they may be bent with the fingers—and a sharp instrument will penetrate them under slight pressure. In brushing the bones with a soft brush, in the process of cleaning specimens, large portions of the teeth are often removed. The tips of the teeth seem to soften first. Distinct cavity formation appears in some cases. This seems to us to be true caries.

Many irregular arrangements of the teeth were brought about. In one animal the lower teeth became carious and were broken off. The upper incisors also became carious, and were broken or rubbed off. All the teeth were affected and softened greatly. The lower jaw, from the incisors to the molars, became decalcified. This animal had to be fed with a medicine dropper. By careful attention to him, we gradually brought him back so that he was able to eat properly. The lower teeth grew out and were fixed in a position in which they were exactly crossed. We had effected decalcification and a subsequent calcification. Later the animal was again placed on the deficient diet, with the formation of large carious areas in his jaws. (In this connection it is to be remembered that the guinea pig is a rodent, and that, under certain conditions, its teeth will continue to grow.)

In a number of other cases the lower teeth became decalcified, elongated, and bent, to such an extent, that the lower first molars touched each other entirely across the jaw. Irregular arrangements of the molars are very common under these conditions. The upper molars of one animal were bent outward at about right angles upon one side of his jaw, while upon the other side the palatal surfaces of the molars disappeared. Opposite them, on the lower jaw, the buccal surfaces of the molars were removed.

Other decalcified areas occur in the maxillary bones and in the bones of the head. In some cases such areas are found at the base of the teeth, the carious process extending entirely through the lower jaw, or at the base of the upper molars within the orbital cavity. Decalcification is often found about the anterior palatal foramen, extending posteriorly to the teeth. Carious areas are found along

the side of the jaw, and in some cases the entire jaw has been affected. The ribs and the leg bones also show marked alteration, although we have observed, particularly, effects upon the teeth and jaws.

We have been able to mark the enamel by feeding, alternately, deficient and normal diets.

The usual joint affections occur to a marked degree; and when this condition has been maintained for a long time, and the animal is then restored to a normal diet, it is found that the legs have become fixed in an abnormal position. This seems to us to be more like rheumatism or arthritis deformans than many experimental conditions that have been called such.

Nervous symptoms are very pronounced at one stage of such deficient feeding. Our efforts to mark the teeth during pregnancy have not been successful, the young being born dead or too prematurely to live. The inhibitory effect upon growth is very noticeable. The tendency to certain infections is evident. Abscesses form about the teeth. Lung and bronchial troubles ensue.

The accompanying illustrations (*figs. 1–50; plates 1–12*) show many of the effects noted above. *Unless otherwise indicated* in the legends opposite the plates, the abnormalities exhibited were due to deficiency of vitamines in the diets, and the animals involved were guinea pigs.

IV. GENERAL CONCLUSION

It is our ability to produce decalcified areas in the bones of the head and in the teeth, with deficient diet, and to effect their recalcification with adequate diet, that is the most striking thing in these experiments.

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PLATES 1–12

(HOWE: FOOD ACCESSORY FACTORS IN RELATION TO THE TEETH)

PLATE 1

FIGS. 1–2. Two animals from the same litter and originally of the same size. *1.*—Fed a normal diet. *2.*—Fed, for a considerable period, a vitamine-deficient diet; shows retardation of growth and development.

FIG. 3 Caries of the left central incisor: the right was decayed and is broken. If tooth decalcification is caries, this is caries—not due to acids of fermentation but to a structural alteration.

(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 2

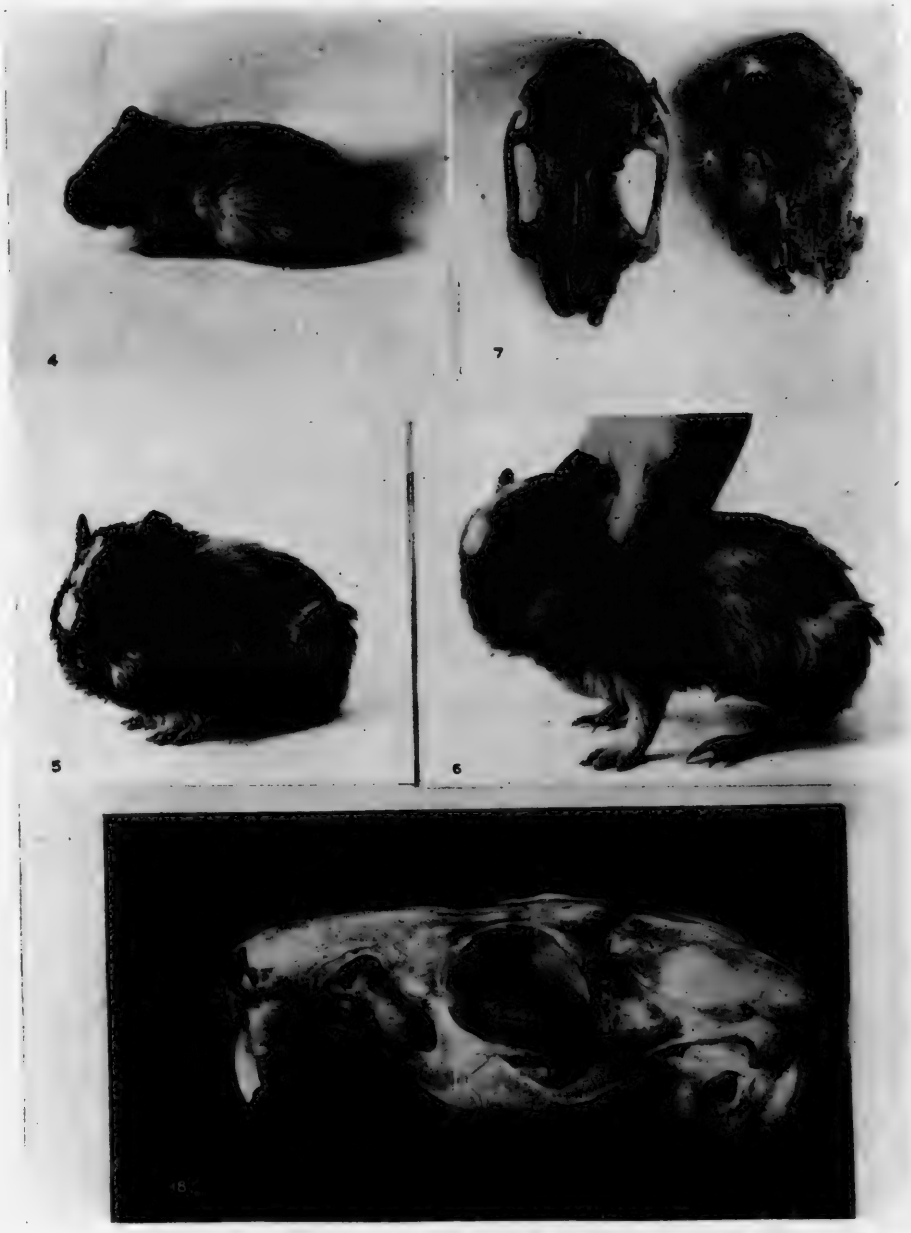
FIG. 4. A distended abdomen is a noticeable feature of vitamine deficiency.

FIG. 5. Tooth abscess following pulp degeneration. This was opened, when about 10 cc. of pus was discharged. The animal was rheumatic for months before the development of the abscess. See *fig. 6*.

FIG. 6. Shows abnormal posture of a leg with ankylosed joint. A result of a return to normal feeding after a period upon a vitamine-deficient diet.

FIG. 7. Bone destruction in skulls (rabbits).

FIG. 8. Decalcified areas in an orbit.



(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 3

FIG. 9. Decalcified areas in an orbit at the base of the teeth.
FIG. 10. Decalcified areas in an orbit.
FIG. 11. Loss of bone in an orbit, with one molar gone.

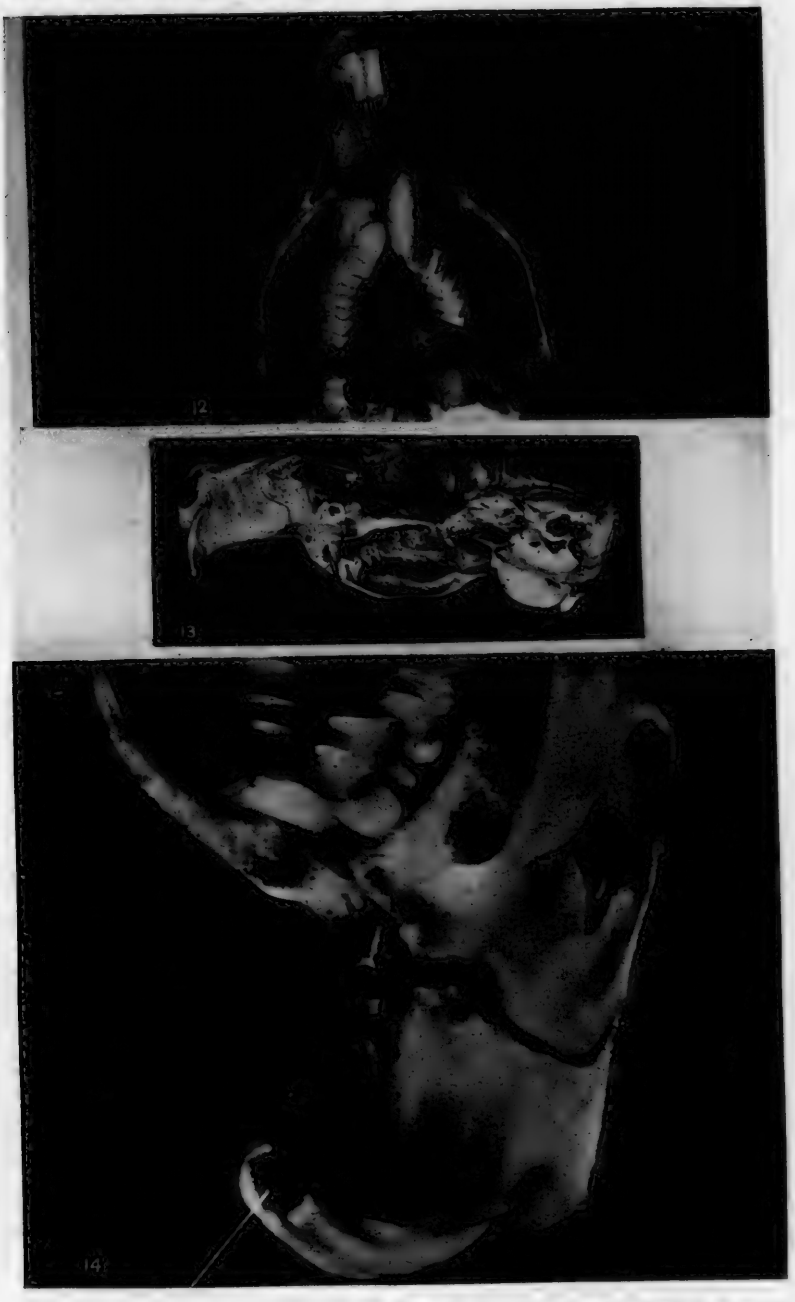
(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 4

FIG. 12. Bony destruction about the root of a first molar.

FIG. 13. Elongation and looseness of teeth.

FIG. 14. Cavities in the incisors, not due to fermentation but to decalcification brought about by a nutritional disturbance.



(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 5

FIG. 15. Decalcification of molars. The necks alone remain fairly well calcified.

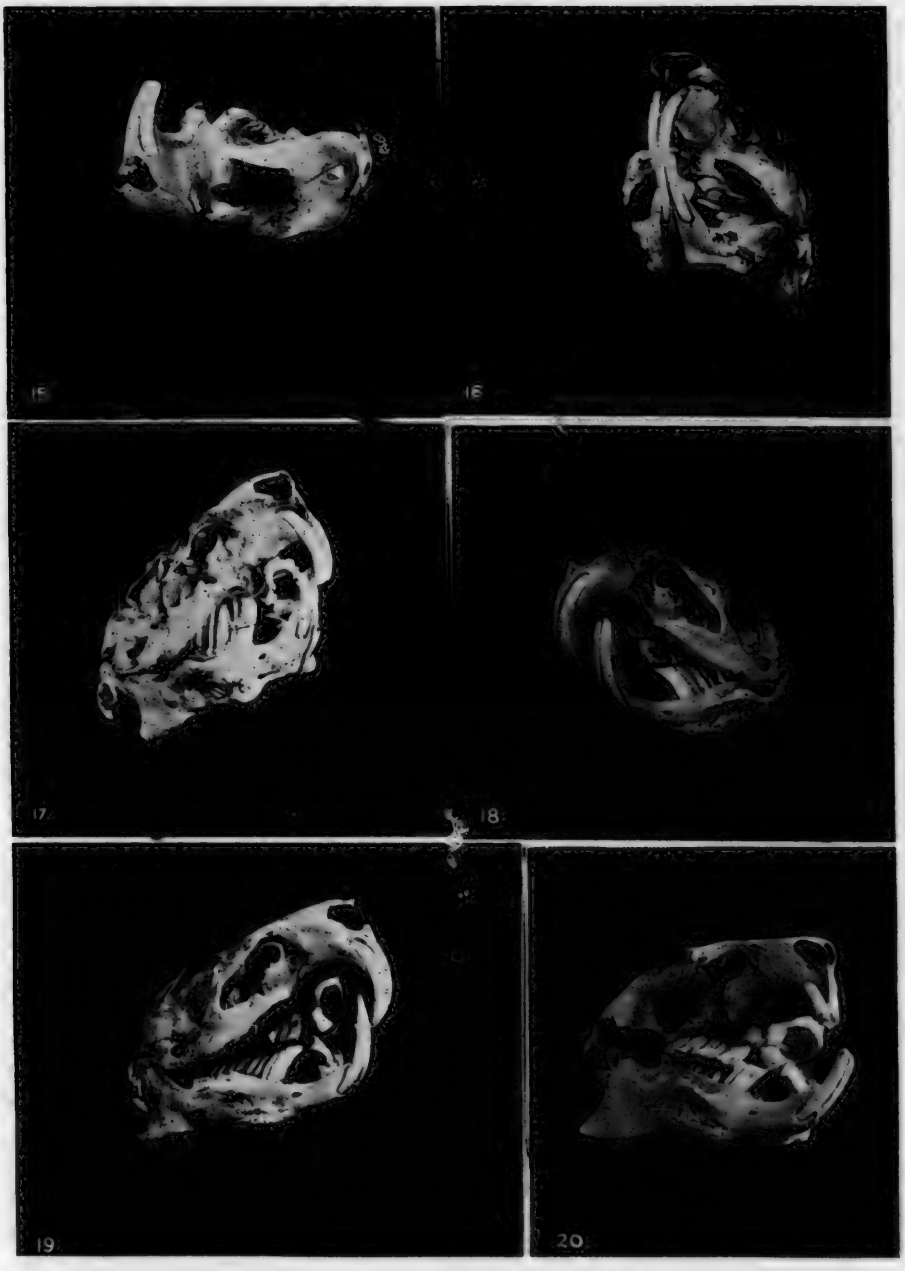
FIG. 16. The necks of molars show fairly sound structure. The articular parts of these teeth are decalcified and like soft cartilage. (See enlarged *fig. 47, plate 11.*)

FIG. 17. Irregularity of the molars. The lingual sides of the lower molars, and the buccal sides of the upper molars, have disappeared. (See enlarged *fig. 48, plate 11.*)

FIG. 18. The molars have curved until they meet across the jaw anteriorly. The incisors are curved and misplaced laterally.

FIG. 19. Lateral irregularity. The molars are curved and bent. The incisors are curved and misplaced. (See enlarged *fig. 49, plate 12.*)

FIG. 20. Irregular articulation. Note the destruction of parts of the incisors.



(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 6

FIG. 21. Irregularity; the teeth were originally perfectly regular. A period of deficient feeding resulted in decalcification of the anterior part of the jaw. The muscular action crossed the teeth. Recalcification followed a return to a normal diet.

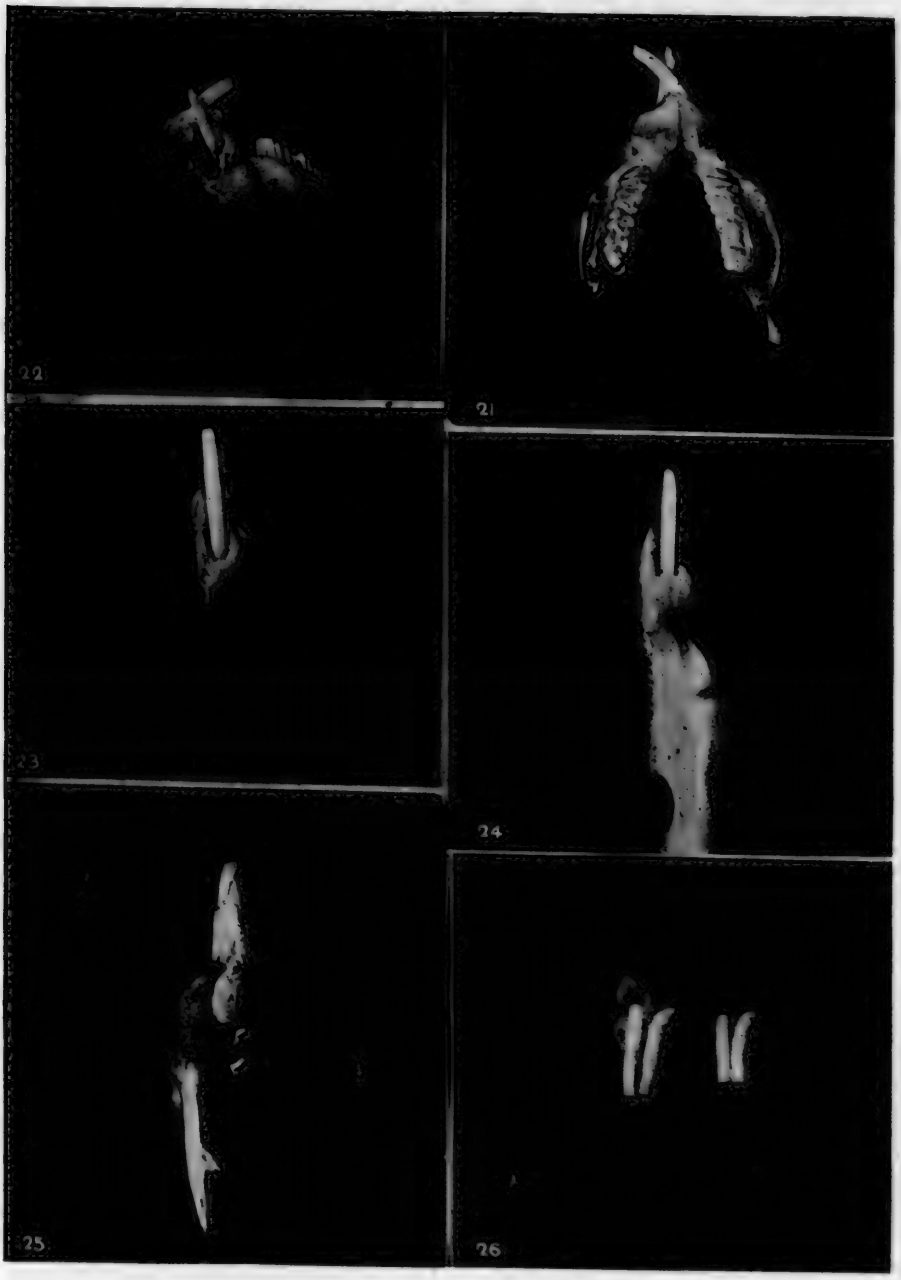
FIG. 22. Carious area about an incisor.

FIG. 23. Loss of bony structure and loosening of an incisor. Fixation of the tooth and calcification of bone occurred after return to a normal diet.

FIG. 24. Decalcification about a lower central incisor, followed by recalcification.

FIG. 25. An area of recalcification extending from the molars, on the lingual side across the base of the jaw, and on the buccal side to the teeth. (See enlarged *fig. 46, plate 10.*)

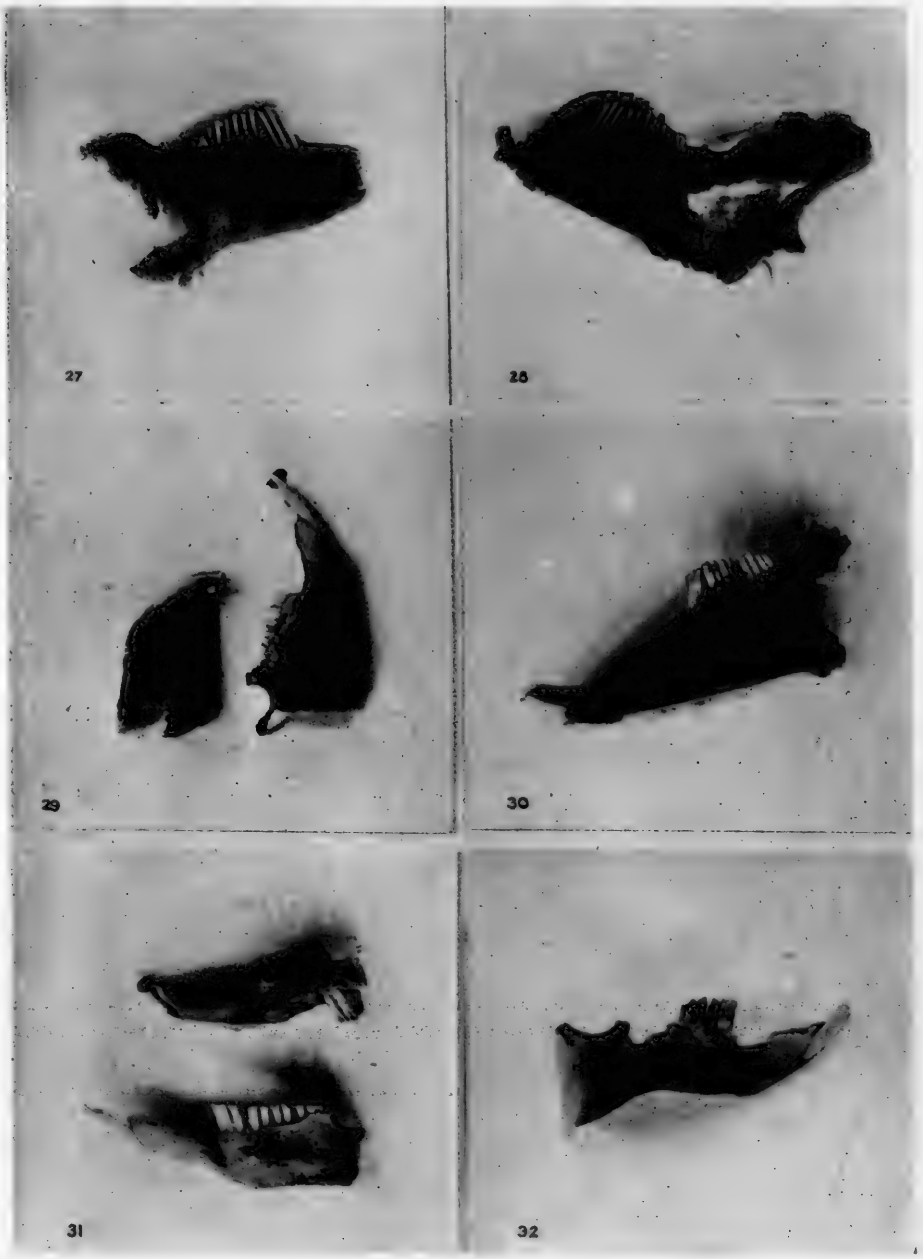
FIG. 26. Enamel markings showing effects of alternate normal feeding and vitamine-deficiency feeding. (See enlarged *fig. 50, plate 12.*)



(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 7

FIG. 27. Carious jaw (rabbit).
FIG. 28. Carious jaw (rabbit).
FIG. 29. Carious jaws (left, guinea pig; right, rabbit).
FIG. 30. Carious jaw (rabbit).
FIG. 31. Carious jaws.
FIG. 32. Carious jaw and teeth.



(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 8

FIG. 33. Loss of the base of a jaw, with the tooth roots exposed.

FIG. 34. Decalcification of part of a jaw. A normal diet has caused recalcification to occur.

FIG. 35. Regulation of the diet has effected partial decalcification followed by recalcification. Note the appearance of the condyle. (See enlarged *fig. 45, plate 10.*)

FIG. 36. A condition similar to pyorrhea, with loss of supporting bony structure.

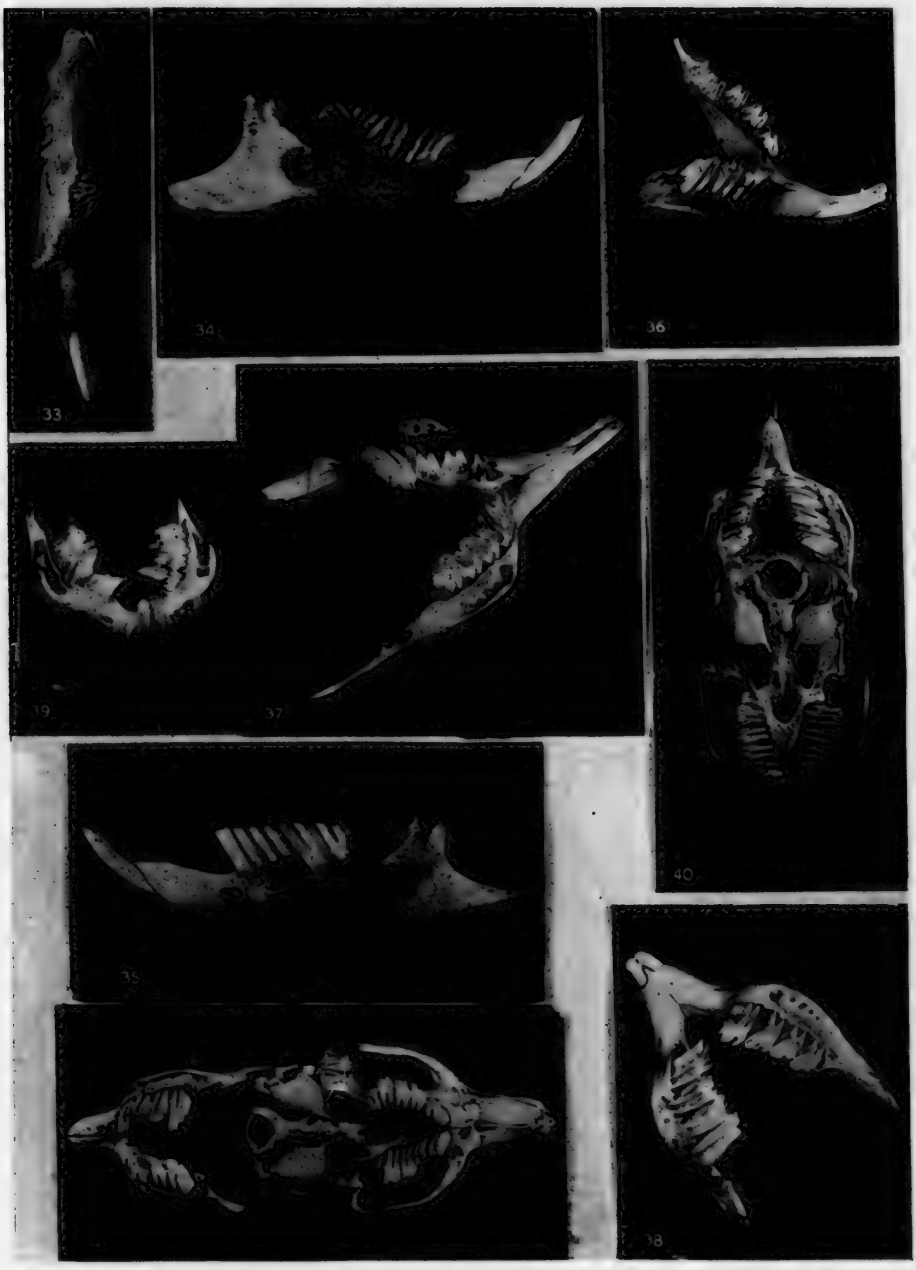
FIG. 37. Loss of alveolar structure; complete on one side.

FIG. 38. Destruction of the alveolar process.

FIG. 39. Lengthening and decalcification of the teeth, with areas of decalcification in the jaw itself.

FIG. 40. Decalcification of teeth and alveolar process.

FIG. 41. Altered tooth structure. Note the feathery tips of the teeth. The lower molars nearly touch. The alveolus is absorbed.



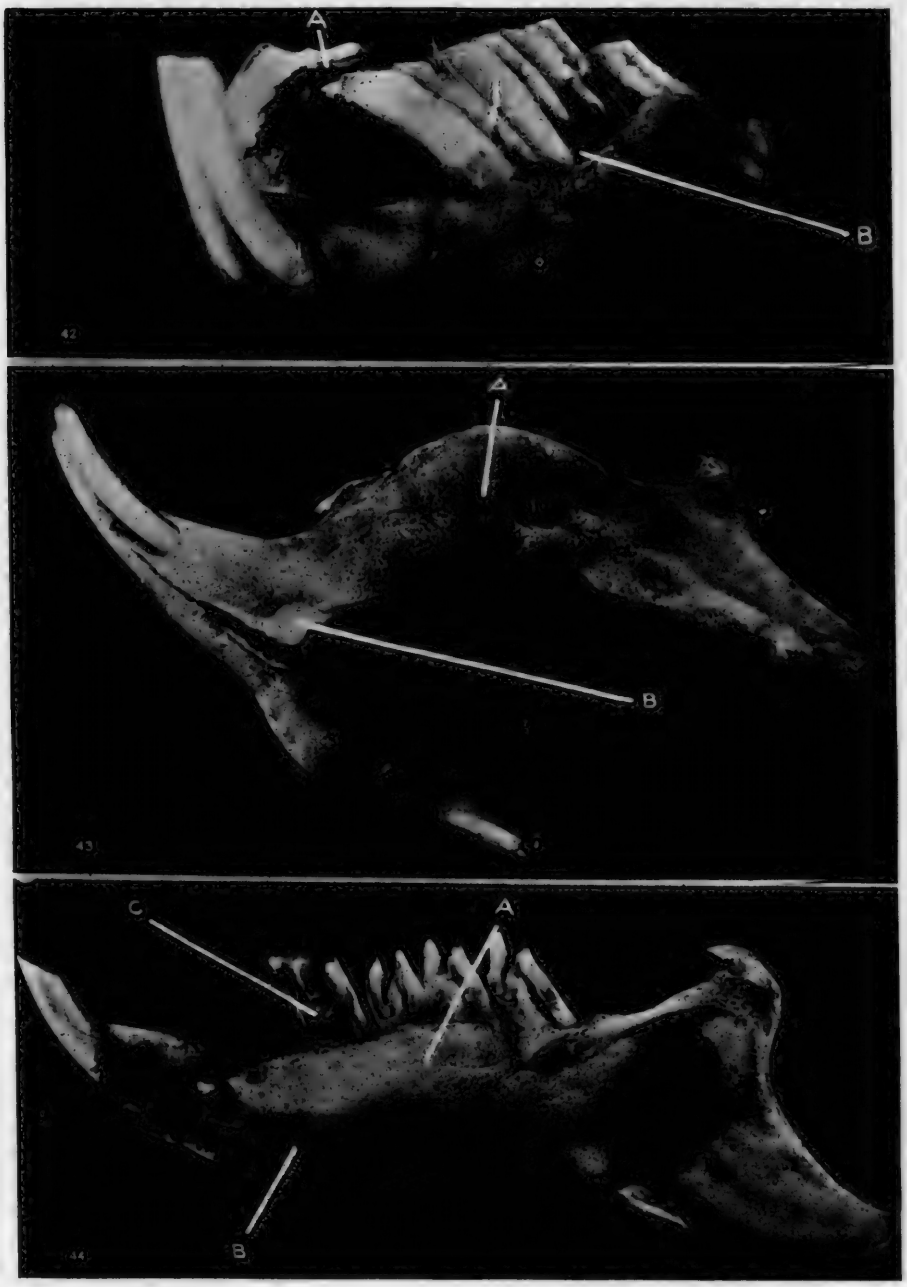
(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 9

FIG. 42. *A*.—Bending of the teeth across the mandible. *B*.—Loss of alveolar structure with looseness of the teeth.

FIG. 43. *A*.—New bone-formation covering a large part of the mandible (length of the experiment, 34 weeks). *B*.—Unaffected part of the jaw.

FIG. 44. *A*.—Large area of forming bone, due to proper feeding after a period of vitamine-deficiency feeding (length of the experiment, 33 weeks). *B*.—Unaffected part of the mandible. *C*.—Tooth destruction.



(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 10

FIG. 45. Destruction of the alveolar process, with loosening of teeth. Carious condyle. The jaw itself is also carious.

FIG. 46. Decalcification; followed by calcification as a result of normal feeding

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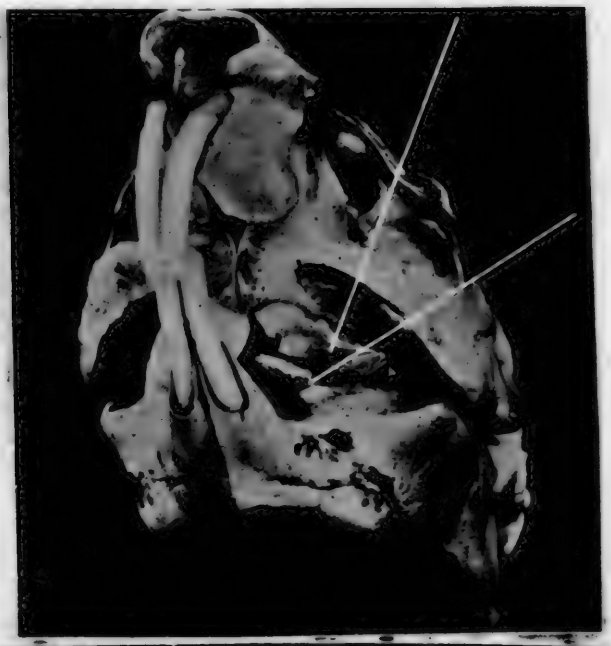
(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 11

FIG. 47. Decalcification of molars.

FIG. 48. *A*.—Lingual side of lower molars decalcified, with subsequent elongation. *B*.—Carious area in the jaw, with molar root exposed.

47



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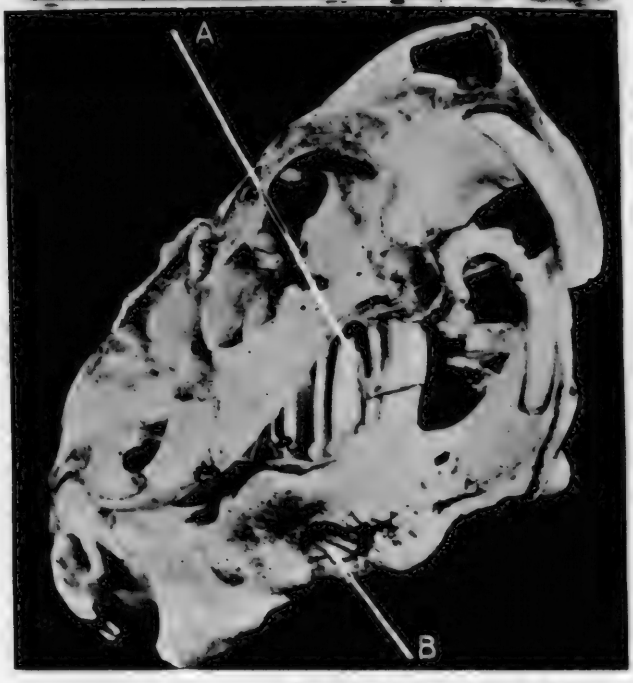
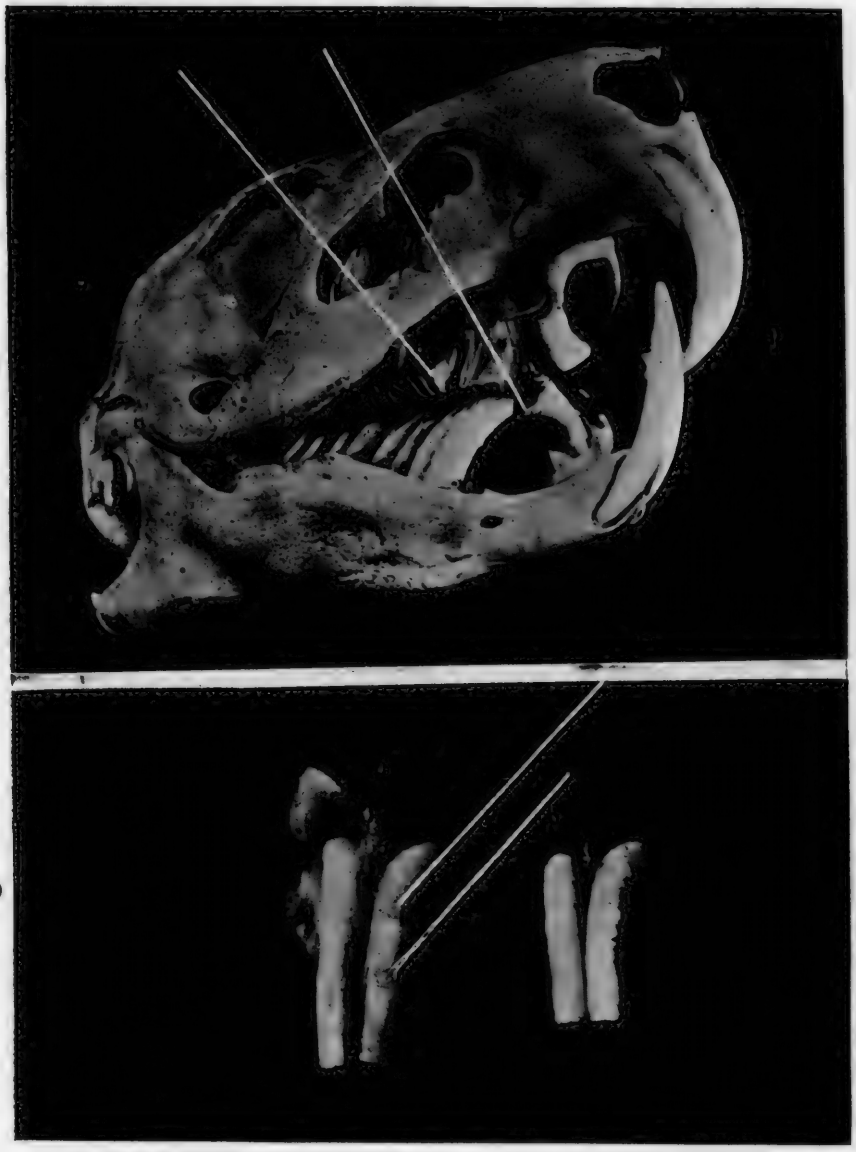


(Howe: Food Accessory Factors in Relation to the Teeth)

PLATE 12

FIG. 49. Decalcification with bending of the teeth. The lower molars are bent inward until they almost meet. The upper molars are bent outward.

FIG. 50. Alternate markings of the enamel, indicating periods of alternate vitamine-deficiency feeding and normal feeding.



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(Howe: Food Accessory Factors in Relation to the Teeth)

A STUDY OF SCURVY AND ITS BEARING ON THE PRESERVATION OF THE TEETH

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I. INTRODUCTION

In this paper we show that scurvy profoundly affects the teeth. We also consider several associated conditions that we thought might have a bearing on human scurvy or on the preservation of the teeth. We found that the loss of calcium from the body was very rapid in scurvy. Examination of the bones showed that they were losing calcified tissue. The teeth of our scorbutic animals became very loose. The dropping-out-of-the-teeth indicates a loss of cementum and possibly of material from the alveolar process. The changes in the teeth proper were surprising. There was marked hyperemia of the pulp with some hemorrhage. The odontoblasts lost their tall columnar form and secreted osteodentine very rapidly. The osteodentine nearly filled the pulp cavity in some cases.

The enamel is formed before the tooth is erupted. The preservation of enamel is probably associated with the composition of the

saliva. An embarrassment in the study of enamel is the difficulty of getting pieces that are not contaminated with other substances. Some writers consider the organic matter reported in the composition of enamel as a contamination. We hoped to avoid this error by using a pure mineral that closely resembles enamel in composition. Since enamel contains fluorine, we selected fluor-apatite as the mineral that most closely resembles enamel, phosphorite seeming to be impure apatite. We selected well-formed crystals of apatite of the composition, $(CaF)Ca_4(PO_4)_3$, and suspended them by gold wires in synthetic saliva of different H-ion concentrations. We found that they lost weight appreciably only in distinctly acid solutions (pH = 5).

We are inclined to accept the view of Pickerill that the function of ptyalin is the cleansing of the teeth by the removal of starch. In the United States army there were found 43,000 upper carious teeth to 26,000 lower carious teeth. Since saliva gravitates to the lower teeth, one might suppose that it protected the teeth by neutralizing acids. We found the alkaline reserve of the saliva of twenty students to vary around 0.01N. The alkaline reserve was found to be increased for some minutes after taking antiscorbutics into the mouth, but this seemed to be a psychic or reflex secretion due to the taste of the antiscorbutics and not lasting long enough to be of any protective value.

Since Pickerill and others observed that savage tribes have good teeth, and one of us has observed this characteristic to apply to tribes of Mexican Indians; and since the army draft boards found better teeth in the States containing the highest proportion of Mexicans; it seemed profitable to inquire whether scurvy might be unknown among such tribes. Scurvy is an ancient disease. Nebuchadnezzar may have had it when he went on all fours and ate grass. A more modern story relates how a sailor, rendered useless in the crew on account of severe scurvy, was put ashore to die; but, being too weak to walk in search of food, he ate grass and was cured. In honor of this event that kind of grass is called "scurvy-grass." Indian troops during the siege of Kut (Hehir, 1919) cured themselves by eating grass, weeds, and horseflesh, after 1050 cases appeared among less than 10,000 troops. One of us (McClendon) has compiled data, to be published in the next issue of this JOURNAL, which show that North American Indians ate hundreds of species of wild plants and

fruits, and that they dried fruits for winter use in such a way as probably to preserve the antiscorbutic powers of the fruits. In this connection we have shown that a commercial preparation of dry orange juice is a powerful antiscorbutic, but we found no antiscorbutic in milk dried by the same process.

The Eskimos called themselves raw-meat-eaters, but we do not know whether meat was their exclusive diet. Accounts of the diet of employees of the Hudson Bay Company give the ration supplied to dog teamsters as 10 pounds of meat or game a day. Dutcher, Pierson and Biester (3) were unable to protect guinea pigs from scurvy on 5 grams of meat a day. We fed 30 grams a day with no signs of protection. Even this quantity of meat was not deleterious, for, with the addition of dry orange juice, the guinea pigs throve on it.

In regard to the question whether we are in danger of scurvy in winter, we tested the antiscorbutic power of canned foods. According to Holst and Fröhlich (5), raspberries are antiscorbutic. We have found that raspberry jam is not antiscorbutic. Tomatoes, from jars kept in boiling water one hour, failed to cure a guinea pig of scurvy. Cucumber pickles had no antiscorbutic action, but sweet-pickled peaches, that had been in boiling water for twenty minutes, and sealed in Mason jars, retained antiscorbutic properties. From these facts we conclude that high temperatures, such as that in the making of jam, or prolonged heating like that in the cold-pack process in the home, destroy the antiscorbutics.

II. CALCIUM METABOLISM IN SCURVY

The analytic determinations, in the experiments described below, were made in portions of the daily (24-hour) output of urine and feces of guinea pigs fed on a calcium-free diet. The fact that the analytic results for successive days are not uniform indicates that the demarcation of 24-hour periods was not perfect. Hence, the data for 72-hour output is more significant than for 24-hour output.

The following calcium-free diet was used in the experiments (1–6):

(1) *Calcium-free orange juice.* The calcium was removed from orange juice by precipitation with oxalic acid. Since 0.1 gram of oxalic acid given subcutaneously is the lethal dose for a guinea pig,

0.05 gram of oxalic acid was added for 10 cc. of orange juice. The orange juice was first filtered by suction and centrifuged. Oxalic acid was then added. After standing overnight the mixture was centrifuged. The supernatant fluid was again allowed to stand overnight and again centrifuged. The clear centrifugate was fed.

(2) *Calcium-free casein.* Prepared by the method of Van Slyke and Baker (9).

(3) *Calcium-free filter paper.* Prepared by soaking the filter paper for several days in 0.3 per cent hydrochloric acid solution and then washing during an equal period with distilled water. (Each sheet weighed 2 grams.)

(4) *Cane sugar.*

(5) *Cottonseed oil* (winter-pressed).

(6) *Distilled water.*

A mixture of casein, 2.5 grams; sugar, 10 grams; oil, 2.5 grams; filter paper, 5 sheets (10 grams); orange juice, 10 cc.; and water, 50 cc., was ashed and a calcium determination made. Only a trace of calcium was found.

Three experiments were performed: one on normal guinea pigs, one on guinea pigs fed on a scurvy diet (consisting of equal parts of white flour and alfalfa meal) for fourteen days, and one on guinea pigs fed on a similar scurvy diet for twenty-one days.

The calcium-free food for the normal pigs (five) consisted of casein, 50 grams; sugar, 200 grams; cottonseed oil, 50 grams; filter paper, 48 sheets (96 grams); orange juice, 200 cc.; distilled water, 100 cc. Water (distilled) was also given ad libitum.

Experiment I. Calcium output in normal guinea pigs on a calcium-free diet, after previous feeding on a balanced (normal) diet (control experiment)

Five normal guinea pigs were given the above diet for sixty hours in order to empty the intestinal tract of all calcium in the previous diet. They were then weighed and continued on the same diet for three days. The urine and feces for three successive 24-hour periods were analyzed together. The determinations of calcium were by Lyman's method (6). Two readings of the nephelometer were

recorded for each 24-hour sample. The duplicate results are given in *table 1*.

TABLE 1

Data pertaining to the output of calcium in normal guinea pigs on a calcium-free diet, after feeding a balanced (normal) diet (control experiment)

	GUINEA PIG				
	1	2	3	4	5
	gm.	gm.	gm.	gm.	gm.
Initial body-weight	370	343	451	520	437
	mgm.	mgm.	mgm.	mgm.	mgm.
Calcium output:					
First day	7.7	4.5	4.1	8.1	7.2
	7.1	4.9	4.6	8.3	7.0
Second day	6.7	9.9	9.0	7.6	7.8
	7.1	8.7	8.7	7.7	
Third day	4.9	7.4	9.3	5.7	8.0
	4.3	7.6	8.0	5.1	
	gm.	gm.	gm.	gm.	gm.
Final body-weight	335	396	412	455	405
Average body-weight	352	415	431	487	421
	mgm.	mgm.	mgm.	mgm.	mgm.
Average daily output of calcium	6.3	7.2	7.3	7.0	7.5
Average daily output of calcium, per 100 grams of guinea pig	1.76	1.71	1.60	1.40	1.78

Experiment II. Calcium output in guinea pigs on a calcium-free diet, after previous feeding for fourteen days on a scurvy diet

The five guinea pigs used in experiment I were subsequently kept on a scurvy diet (equal parts of white flour and alfalfa meal) for fourteen days. They were then put back on the calcium-free diet used in experiment I, except that the orange juice was omitted. After forty-eight hours on this calcium-free diet, the urine and feces were collected and analyzed as before. The analytic data are given in *table 2*.

TABLE 2

Data pertaining to the output of calcium in guinea pigs on a calcium-free diet, after feeding for fourteen days on the scurvy diet

	GUINEA PIG				
	1	2	3	4	5
	gm.	gm.	gm.	gm.	gm.
Initial body-weight	300	345	345	380	355
	mgm.	mgm.	mgm.	mgm.	mgm.
Calcium output:					
First day	8.7	9.7	8.9	17.0	13.5
	8.3	10.5	9.4	18.0	14.2
Second day	11.9	4.1	8.7	10.8	9.6
	11.2	3.8	8.9	10.2	9.1
Third day	11.5	8.9	6.2	14.8	14.0
	12.2	9.3	5.8	16.0	13.4
	gm.	gm.	gm.	gm.	gm.
Final body-weight	270	325	325	350	325
Average body-weight	285	335	335	365	340
	mgm.	mgm.	mgm.	mgm.	mgm.
Average daily output of calcium	10.6	7.7	7.9	14.4	12.3
Average daily output of calcium, per 100 grams of guinea pig	3.7	2.2	2.3	3.9*	3.6

* This guinea pig, showing the greatest calcium output per 100 grams, died on the day after the completion of the experiment, and at autopsy showed hemorrhages and other signs of scurvy.

Experiment III. Calcium output in guinea pigs on a calcium-free diet, after previous feeding for twenty-one days on a scurvy diet

We selected, for this experiment, five guinea pigs that had not previously been used, but which had been kept on the scurvy diet for twenty-one days. The animals were then put on the calcium-free diet for forty-eight hours, during which the urine and feces were collected and analyzed as before. The data are given in *table 3*.

It might be objected that possibly calcium elimination depends on age and not on weight. Such a possibility does not upset our conclusions, however. The average age in experiment II was greater, and in experiment III was less, than that in the control experiment—I.

TABLE 3

Data pertaining to the output of calcium in guinea pigs on a calcium-free diet, after feeding for twenty-one days on the scurvy diet

	GUINEA PIG: NUMBER AND SEX				
	1 ♂	2 ♀	3 ♀	4 ♀	5 ♂
	gm.	*gm.*	*gm.*	*gm.*	*gm.*
Initial body-weight	325	195	245	310	285
Body-weight when the feeding of the scurvy diet was started	336	188	250	335	314
	mgm.	*mgm.*	*mgm.*	*mgm.*	*mgm.*
Calcium output:					
First day	?	6.1 6.6	9.2 9.6	?	?
Second day	9.9 9.4	7.2 7.5	7.9 8.2	14.1 15.0	13.1 13.3
Third day	10.4 10.8	7.8 7.6	Died	12.6 11.8	9.8 10.0
	gm.	*gm.*	*gm.*	*gm.*	*gm.*
Final body-weight	310	175	210	290*	260
Average body-weight	325	185	227	300	272
	mgm.	*mgm.*	*mgm.*	*mgm.*	*mgm.*
Average daily output of calcium	10.1	7.1	8.7	13.4	11.3
Average daily output of calcium, per 100 grams of guinea pig	3.1	3.8	3.8	4.4	4.1
Adrenals (per cent of body-weight)		0.154	0.100	0.130	0.100

* Died.

III. FORMATION OF OSTEODENTINE IN THE TEETH IN SCURVY

Addison and Appleton (1) have shown that, as the crown of the incisor tooth of the white rat is worn away, the pulp cavity is closed by an irregular formation of dentine just below the worn surface. We have observed this formation in normal guinea pigs also; it may be called osteodentine. But the osteodentine that we have observed in the pulp cavity of the guinea-pig incisor, in scurvy, is perhaps one hundred times as bulky as that in the normal animal. A drawing of a cross section of the normal incisor may be seen in *figs. 1* and *2*. The odontoblastic layer is a tall columnar layer of cells, and the inner surface of the dentine is smooth. The pulp is well supplied with blood vessels, but the blood corpuscles are confined to these vessels. A drawing of a cross section of an incisor at about the same level, but

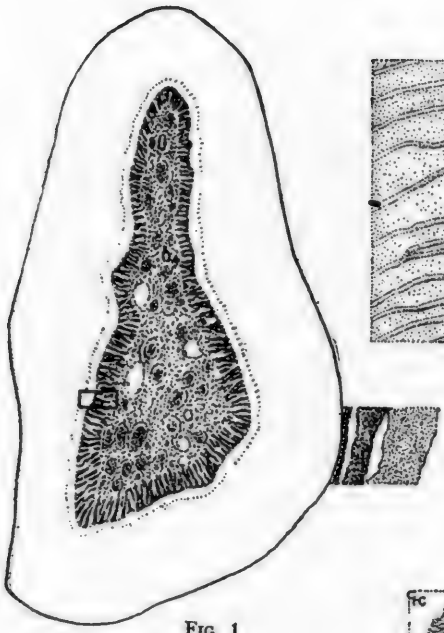

FIG. 1

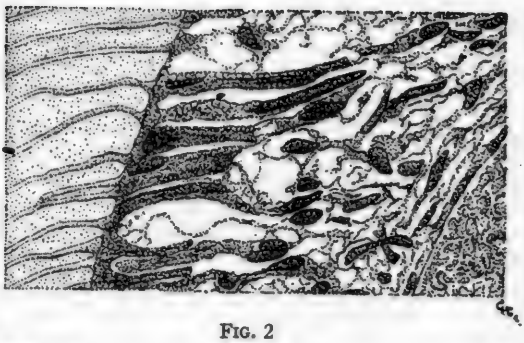

FIG. 2

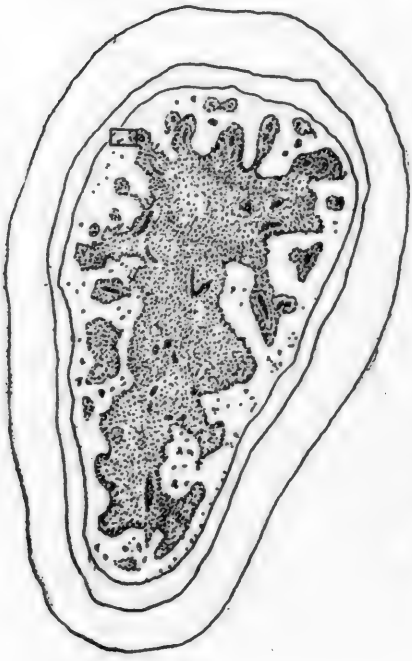

FIG. 3

FIG. 4

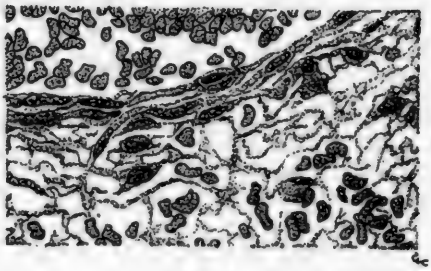

FIG. 5

from a scorbutic guinea pig, is shown in *figs. 3*, *4*, and *5*. The odontoblasts have lost their columnar form, and some of them are enclosed in osteodentine. The osteodentine completely encloses the pulp cavity; it is quite thick, and its inner surface is thrown into folds. There is, apparently, hyperemia of the pulp; and red blood corpuscles may be seen outside the blood vessels, among the cells of the pulp. We have sectioned teeth of quite a number of guinea pigs and always find these marked changes if antiscorbutics were not included in the diet. We do not understand why Zilva and Wells (10) failed to observe the osteodentine in scurvy, unless it was altered by decalcification. We decalcified *in the fixing fluid* (Zenker's fluid, with 10 per cent acetic acid).

IV. INFLUENCE OF ANTISCORBUTICS ON THE ALKALINE RESERVE OF SALIVA

Immediate local effect. The experiments were conducted on one man, and were commenced from one and a half to two hours after the

FIG. 1. NORMAL TOOTH (× 40), WITH A SMALL PIECE OF PERIDENTAL TISSUE ATTACHED[1]

The stippled line in the dentine represents deeper staining and not a refractive line.

FIG. 2. DRAWING OF THE AREA IN FIG. 1 MARKED BY THE RECTANGLE (× 600)

Note the tall columnar layer of odontoblasts with processes extending into the canals of the dentine.

FIG. 3. SCORBUTIC TOOTH (× 40), SHOWING THE WHITE OSTEODENTINE INVADING THE DARK PULP AND ENCLOSING GROUPS OF ODONTOBLASTS AND SINGLE ODONTOBLASTS

FIG. 4. DRAWING OF THE PORTION OF FIG. 3 MARKED BY THE RECTANGLE (× 600)

The osteodentine, represented by the stippled area, is seen to enclose two odontoblasts.

FIG. 5. DETAIL OF ANOTHER SCORBUTIC TOOTH (× 600), SHOWING PART OF A BLOOD VESSEL CONTAINING CRENATED ERYTHROCYTES AND A FEW CRENATED ERYTHROCYTES OUTSIDE THE VESSEL, BETWEEN THE PULP CELLS

[1] *Figures 1–5* are drawn from serial cross-sections of guinea-pig teeth, at a level below the gums but far from the apex of the root. The teeth were fixed and decalcified in Zenker's fluid containing 10 per cent of acetic acid; imbedded in paraffin; sectioned and stained on the slide with Dominici's eosin, orange-G and toluidin-blue solution. The enamel is completely removed by the decalcification.

noon-day meal. The mouth was rinsed with water and a flow of saliva obtained by chewing paraffin. The saliva was collected in a beaker and centrifuged. Ten cc. were then placed in a flask, 0.4 cc. of 0.04 per cent phenolsulfonephthalein added as an indicator, and 20 cc. of N/100 HCl. This was then rotated by machine for five minutes with a stream of CO_2-free air blowing through it. It was then titrated against N/100 NaOH, being compared with a standard pH = 7,

TABLE 4

Data pertaining to the immediate influence of antiscorbutics on the alkaline reserve of saliva, after the introduction of antiscorbutics into the mouth

FOOD (ANTISCORBUTIC USED)	NORMAL ALKALINE RESERVE	ALKALINE RESERVE 10 MINUTES AFTER TAKING THE ANTISCORBUTIC INTO THE MOUTH	INCREASE IN THE ALKALINE RESERVE
	N	*N*	*N*
Lemon	0.0066	0.0116	0.0050
	0.0069	0.0136	0.0067
Sour orange	0.0060	0.0101	0.0041
	0.0060	0.0091	0.0031
Apple	0.0055	0.0106	0.0051
	0.0065	0.0126	0.0061
	0.0110	0.0146	0.0036
Sweet orange	0.0060	0.0061	0.0001
	0.0085	0.0091	0.0006
	0.0064	0.0080	0.0016
	0.0070	0.0116	0.0046
Banana	0.0070	0.0086	0.0016
	0.0050	0.0066	0.0016
Celery	0.0059	0.0062	0.0003
	0.0068	0.0067	

made with the same indicator, so that exactly the same end point was reached in all the experiments.

The antiscorbutic was taken into the mouth. Ten minutes later the mouth was rinsed, the saliva collected, and determination of the alkaline reserve made in exactly the same manner as before.

From six control determinations it was found that a second specimen of saliva, collected by chewing paraffin after an interval of ten

minutes, showed an increased alkaline reserve of 0.0004 N over the first specimen. Therefore, any increase after the oral introduction of antiscorbutics must be greater than this to be ascribable to the antiscorbutic used in these tests. (*Table 4.*)

In several determinations it was found that the increased alkaline reserve after taking lemons, apples, etc., was only temporary, the alkaline reserve returning to normal in from forty minutes to an hour and a quarter. As to other constituents of the foods, besides antiscorbutics, H-ions caused an increase and sugar a decrease in alkaline reserve.

TABLE 5

Data pertaining to the ultimate influence of a scurvy diet (acid-ash) on the alkaline reserve of saliva

FIRST EXPERIMENT: NORMAL = 0.0080 N		SECOND EXPERIMENT: NORMAL = 0.0070 N	
Day	Alkaline reserve of the saliva	Day	Alkaline reserve of the saliva
	N		*N*
1	0.0080	1	0.0070
2	0.0090	2	0.0078
3	0.0069	3	0.0065
4	0.0049	4	0.0059
5	0.0047	5	0.0055
6		6	0.0041
7	0.0040	7	0.0042
8	0.0040	8	0.0041
9	0.0039	9	0.0043

Ultimate systemic effect of a scurvy diet. An attempt was next made to determine whether or not an acid-forming or an alkali-forming diet would affect the alkaline reserve of the saliva. Consequently, the normal was again determined and then the subject ate only such foods as yield an acid ash, the chief of these being bread and meat, and excluding milk, fruits, and vegetables (this was, therefore, a scorbutic diet). Two such experiments were performed on one individual—the second, one month after the first—with the results shown in *table 5*.

In each case the lowered alkaline reserve of the saliva returned to normal in about one week after the resumption of a normal diet.

An alkali-forming diet, consisting of milk, fruits, and vegetables (and therefore antiscorbutic) was next taken, but in two experiments extending over ten days no change in the alkaline reserve was noted. Sodium bicarbonate, in 50-gram doses, increased the alkaline reserve of the saliva, but this may have been partly due to reflex stimulation. The data of the latter tests are given in *table 6*.

TABLE 6

Data pertaining to the immediate effects of sodium bicarbonate, after its introduction into the mouth, on the alkaline reserve of saliva

EXPERIMENT NUMBER	ALKALINE RESERVE (NORMAL)	SODIUM BICARBONATE TAKEN	ALKALINE RESERVE	
			Thirty minutes later	Two hours later
	N	*gm.*	*N*	*N*
1	0.0080	50	0.0091	0.0081
2	0.0066	50	0.0072	0.0071

V. ON THE SOLUBILITY OF APATITE IN "SYNTHETIC SALIVA"

A great deal has been said about "acid mouth," and its destruction of the teeth. In a class of twenty students on which determinations were made of the H-ion concentration of the saliva collected in the manner described above, none was found whose saliva was not alkaline (pH about 7.5), although it was neutral (pH = 7) at a CO_2-tension of 40 mm. Hg. The question then arises whether or not the teeth will dissolve in saliva, and if so at what pH. Enamel is difficult to obtain pure and free from cracks. The hard substance of nearest resemblance to it is fluor-apatite, $(CaF)\ Ca_4\ (PO_4)_3$. Apatite[2] was used in place of enamel; and, since it is a related substance chemically, it serves as a basis of significant comparison, at least. Likewise, saliva could not be used because of the large amount required for the tests! Consequently, twenty liters of a saliva-like solution were made, in distilled water, with the following molecular composition: KH_2PO_4, 0.0025 m.; $NaHCO_3$ (alkaline reserve), 0.01 m.; KCl, 0.02 m.; $CaCl_2$, 0.003 m. These are approximately the amounts of the diffusible salts in saliva; the values for phosphates and alkaline reserve were taken from our own analytic determinations; the total

[2] We are indebted to Prof. W. H. Emmons for the crystals of apatite.

chlorides, of calcium and potassium, from the literature. Four 4-liter "Nonsol" flasks were filled into the neck with this solution; CO_2 or HCl was added to obtain the desired H-ion concentration, one being made pH = 5, one pH = 5.5, one pH = 6.5, and one pH = 7. Unfortunately, the one at pH = 7 was accidentally broken. Three large crystals of apatite were then thoroughly washed, dried in an oven at 110°C., cooled in a desiccator, weighed, and then suspended by gold wires in the different flasks, which were then closed with rubber stoppers. At the end of three days the crystals of apatite were removed, washed, dried, weighed, and again replaced in the solutions. Two months later the same process was repeated.

TABLE 7

Data pertaining to the loss in weight of apatite suspended in "synthetic saliva" of different degrees of acidity

"SYNTHETIC SALIVA"		APATITE CRYSTALS				
Specimen number	Acidity	Original weight	Weight after immersion for three days	Weight after immersion for two months longer	Total loss of weight in	
					Three days	Two months and three days
	pH	*gm.*	*gm.*	*gm.*	*mgm.*	*mgm.*
1	6.5	2.7272	2.7266	2.7262	0.6	1.0
2	5.5	2.7024	2.7022	2.7021	0.2	0.3
3	5.0	2.5942	2.5895	2.5270	4.7	67.2

The various weights, recorded in *table 7*, show loss in weight of the apatite in the pH = 5 solution and an insignificant loss in the others. The surface of the apatite was eroded in the pH = 5 solution.

VI. ON THE SCORBUTIC INFLUENCE OF A DIET OF RAW REFRIGERATED LEAN BEEF AND THE ANTISCORBUTIC EFFECT OF DRY ORANGE JUICE

Owing to the discrepancy between the data for men and guinea pigs on the question whether meat contains antiscorbutics, we decided to feed large amounts of raw meat to guinea pigs, to test the matter for ourselves. We found that guinea pigs ate meat the more readily, the younger they were when they were started on it, and that they were attracted to it when it was covered with a little alfalfa meal and freshly prepared for them, in this way, several times a day. The

TABLE 8

Data pertaining to the influence, on the body-weight of guinea pigs, of a raw lean-beef diet, and to the antiscorbutic effect of dry orange juice

DAY OF OBSERVATION	COMPARATIVE DIETS											
	Alfalfa and wheat flour		Raw lean beef (plus dry orange juice on the days indicated below by the asterisks)									
	Two control animals		Ten treated animals									
	1	2	3	4	5	6	7	8	9	10	11	12
No.	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*
1	120	236	105	109	107	138	156	233	242	143	129	180
2	119	233	101	106	110	131	134	224	235	139	118	168
3	135	227	100	105	108	122	142	215	236	135	109	169
4	130	225	100	104	107	120	144	212	230	130	Dd[2]	169
5	134	231	104	106	113	120	143	201	213	123		159
6	140	235	88	105	111	115	150	190	207	125		156
7	140	256	89	108	116	123	152	188	200	134		144
8	142	256	100	117	120	121	151	180	191	136		146
9	147	268	103	111	119	126	148	Dd[2]	Dd[2]	144		147
10	132	267	109	108	119	131	147			145		142
11	138	274	110	114	119	130	154			141		145
12	150	275	118	115	122	134	160			142		152
13	144	293	114	117	123	148	162			148		155
14	158	291	125	124	133	163	163			154		165
15	155	293	120	121	135	160	166			150		164*
16	156	300	123	126	141	177	170			152		180
17	161	307	123	130	142	178	168			154		183
18	171	303	129	133	143	180	165			158		195
19	165	306	133	135	141	192	165			168		207*
20	170	300	127	131	145	195	155			156		195
21	165	298	131	140	144	195	153			167		205*
22	165	284	130	130	140	169	139			165		213
23	168	280	127	133	146	Dd[2]	127			163		225*
24	163	281	120	126	143		Dd[2]			162		219*
25	165	277	Dd[2]	111*	142*					Dd[2]		226*
26	Kld[1]	277		Dd[2]	145*							232*
27		277			153*							230*
28		275			155*							234*
29		267			158*							230*
30		261			164*							248*
31		244			165*							246*
32		237			170*							258*
33		217			179*							260*
34		210			181*							272*
35		Dd[2]			185*							270*
36					187*							275*
37					194*							276*

[1] "Kld" signifies killed.

[2] "Dd" signifies died.

control guinea pigs were fed equal parts by weight of alfalfa meal and white wheat flour; but, owing to the fact that some of the animals seemed young enough to be nursed by their mothers, both controls and meat-eaters were given equal quantities of pasteurized milk for a number of days and then the milk was stopped for all guinea pigs at the same time. The antiscorbutic in the milk may explain the long life of one control (see *table 8*). The quantities of alfalfa meal and flour for the controls and of meat for the meat-eaters were unlimited, but occasionally the quantities eaten were determined. Some of the guinea pigs ate 30 grams of meat a day. The data for body-weights of the animals are given in *table 8*.

Of the controls, no. 1 began to show symptoms of scurvy on the twenty-first day, and had a marked degree of scurvy when killed and autopsied on the twenty-sixth day. No. 2 was larger and therefore more resistant, but died of scurvy on the thirty-fifth day.

Of the animals on the meat diet, nos. 8, 9 and 11 disliked the meat and died too early to show symptoms of scurvy. All of the others exhibited marked degrees of scurvy and all died of it except nos. 5 and 12, which were cured with dry orange juice. No. 4 was given dry orange juice the day of his death. It seems possible that he was cured of the metabolic changes characteristic of scurvy but died of the secondary effects of hemorrhages already present. The effect of dry orange juice on appetite is immediate. No. 5 was losing about 4 grams in weight per day and had ceased to eat when it was given dry orange juice on the twenty-fifth day. It immediately began to eat and to gain about 5 grams a day to the end of the experiment (a gain of 52 grams in twelve days). The rate of gain of no. 12 was even greater—112 grams in twenty-two days after feeding dry orange juice. Each of these guinea pigs continued to eat 30 grams of meat per day, showing that the meat was not deleterious. No. 4 showed marked scurvy on the twenty-fourth day; there was great swelling and tenderness of the wrist joints, and blood in the stools, both symptoms clearing up, however, on the dry orange juice. This animal[3] is shown, in *fig. 6*, drinking a solution of dry orange juice.

[3] We are indebted to Rath Mills and Bell, Inc., for the photograph of the guinea pig that was cut from a motion-picture film.

The orange juice was dried by spraying it through warm air until it was reduced to about one-fourth or less of its original weight; then the drying was continued by bubbling dry air through the juice until it became a very stiff paste at about one-fifth of its original weight and could be kept in open vessels without molding. The temperature was kept low enough to avoid a "pasteurized taste." Since the quantity given one animal per day was a very few tenths of a gram, we do not suppose that the sugar in it had much to do with the change

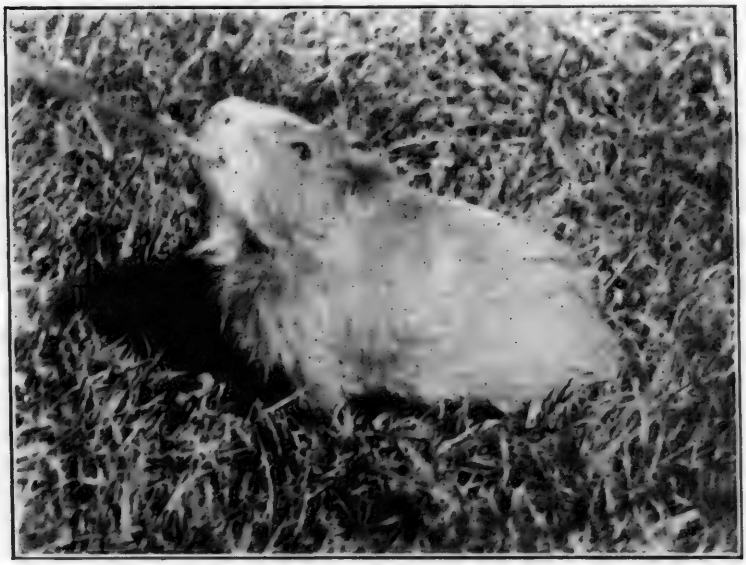

FIG. 6. CUT-OUT OF MOTION PICTURE OF GUINEA PIG THAT HAD BEEN CURED OF SCURVY WITH DRY ORANGE JUICE; DRINKING A SOLUTION OF THE DRY JUICE FROM A PIPETTE

This guinea pig cries for the juice and is not satisfied with the measured dose.

in the weight curve (from a loss of 4 grams a day to a gain of 5 grams a day). This outcome indicates that loss in weight is one of the symptoms of scurvy and that the antiscorbutic increases the appetite (the antineuritic vitamine in the orange juice being small in amount in comparison with that in the meat).

VII. THE EFFECT OF PRESERVATION ON THE ANTISCORBUTIC VALUE OF SOME FOODS

In the work described in the last preceding section, we failed to detect antiscorbutics in refrigerated beef but found that dry orange juice had a powerful antiscorbutic action. Further experiments by Dr. W. S. Bowers indicate that orange juice loses none of its antiscorbutic power on being dried by the method described on page 54. We believed it would be instructive to determine the effect, on milk, of the same method of drying; and the effect on other foods, of different methods of canning.

Milk was pasteurized before being dried and hence was probably very low in antiscorbutic power before drying. The spray of milk fell to the bottom of the drying chamber in the form of a powder containing about 5 per cent of moisture. After the powder was mixed with water, and after standing, a rich cream (not butter) formed at the top. The enzymes in the milk were not destroyed.

Tomatoes were canned in the home by removing the skins, packing cold in Mason jars, and immersing in boiling water for one hour. Peaches were "sweet pickled," that is to say, they were kept in the boiling pickle for twenty minutes and then sealed in Mason jars. Raspberries were boiled, in an open vessel with the addition of sugar, to the consistency of jam. The large sugar content raised the boiling temperature. Cucumber pickles in the form of a commercial product were used.

Two experiments were made: the first was an attempt to cure, and the second to prevent, scurvy; and were conducted in the manner, and with the results, shown in *table 9*.

In the first experiment, on the eighteenth day (*table 9*), additions were made to the scorbutic diet for the first four guinea pigs as follows: no. 1 received 15 grams of the canned tomato; no. 2, 20 grams of sweet pickled peaches; no. 3, 6 grams of raspberry jam; no. 4, 10 grams of cucumber pickle. Since the animals would not eat larger quantities, they were given these same quantities each succeeding day until their death. The animals on tomato, jam and cucumber died on the twenty-first day (on the same day with the control, which was on an oat diet). This result indicates that the additions had

TABLE 9

Data pertaining to the influence of various methods of preservation of milk and fruits on the antiscorbutic value of such foods

I. Basal diet of oats, with a little evaporated milk (and the additions of preserved fruits indicated below)

DAY OF OBSERVATION	BODY-WEIGHTS OF THE FIVE GUINEA PIGS					
	1	2	3	4	5 (control)	
No.	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	
1	165	230	170	158	152	
2	165	233	176	158	155	
3	168	250	190	165	157	
4	168	254	183	159	157	
5	170	260	189	166	162	
6	170	258	185	172	159	
8	167	252	188	170	161	
9	165	238	180	172	164	
10	162	235	186	172	164	
11	165	254	184	170	164	
13	155	235	187	169	169	
15	145	220	188	169	161	
16	139	220	175	169	161	
17	130	215	172	164	158	
18	127	206	166	164	156	
	Tomato (15 gm.) daily	Sweet pickled peach (20 gm.) daily	Raspberry jam (6 gm.) daily	Cucumber pickle (10 gm.) daily		
19	119	197	164	156	151	
20	113	195	154	134	135	
21	Died	190	Died	Died	Died: adrenals = 0.115 per cent of body-weight (♂)	
22		190				
23		192				
24		190				
25		183				
26		183				
27		175				
28		166				
		Died: adrenals = 0.122 per cent of body-weight				

TABLE 9—*Continued*

II. Basal diet of alfalfa meal with an equal weight of white flour (and the additions—20 grams each—of milk or preserved fruit, as indicated below)

DAY OF OBSERVATION	BODY-WEIGHTS OF THE SIX GUINEA PIGS					
	1	2	3	4	5	6
	Raspberry jam	Sweet pickled peaches	Cucumber pickle	Dry milk	Dry milk	Control: basal diet only
No.	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*	*gm.*
1	275	323	318	349	238	310
3	255	292	310	311	195	280
5	258	293	311	296	179	272
7	260	307	310	297	193	278
9	270	319	320	290	194	288
10	268	313	316	294	192	294
12	269	309	309	304	199	302
14	270	314	312	305	210	294
16	265	318	294	305	315	290
20	265	327	300	311	217	282
23	265	335	297	287	213	284
28	220	317	235	243	172	196
29	210	313	222	242	156	187
		Peaches discontinued	Died: adrenals = 0.153 per cent of body-weight			Died: adrenals = 0.177 per cent of body-weight
30	210	290		243	142	
					Died: adrenals = 0.211 per cent of body-weight	
31	202	300		235		
32	179			221		
	Died: adrenals = 0.190 per cent of body-weight			Died: adrenals = 0.199 per cent of body-weight		
36		215				
37		200				
		Died: adrenals = 0.175 per cent of body-weight (♀)				

very little antiscorbutic value. In the case of tomato this is surprising since it is regarded as a reliable antiscorbutic even in the canned condition. Perhaps the heating in boiling water for one hour destroyed the antiscorbutic principle. The result suggests that hot-pack with a shorter period of heating is superior to cold-pack with prolonged heating. The sweet pickled peaches were boiled for only twenty minutes and had some antiscorbutic value, as evidenced by the fact that the guinea pig to which it was fed lived a week longer than the others.

In the second experiment the basal diet was equal parts of alfalfa meal and white flour, and the supposed antiscorbutic foods were fed from the start, 20 grams a day to each animal. In the cases of jam and cucumber, some of this was not eaten. On the twenty-ninth day the peaches were discontinued. The animal that had received them lived eighteen days longer on the basal diet alone, or only three days less on a scurvy diet than the fifth animal (control) in the first of these two experiments, indicating that the peaches were nearly sufficient for the animal's antiscorbutic needs (at least in addition to the alfalfa meal). The fact that the control animal in the second experiment lived longer than that in the first experiment may be due to their difference in size or to a slight antiscorbutic value of the dry alfalfa. Apparently the raspberry jam, cucumber pickle and dry milk have little antiscorbutic value.

VIII. IS EDEMA OF THE ADRENAL A SYMPTOM OF SCURVY?

According to McCarrison (7), edema of the adrenal occurs in scurvy. He gives the weights of the adrenals but not the sex of the guinea pigs. In scurvy, we found that the weight of the adrenals varied from 0.1 to 0.2 per cent of the body-weight at the time of death, for the guinea pigs mentioned in this paper. The sex was not always recorded, but from the cases in which it was recorded no sex distinction, in size of adrenal, is evident.

As a control on this matter, we took a male guinea pig at the time of weaning and fed him on cabbage until he was exactly 200 grams in weight, then killed him and weighed the adrenals (*his teeth were sectioned and are shown in figs. 1 and 2*). His adrenals were 0.05 per cent

of his body-weight. It might appear, therefore, that scurvy increases the size of the adrenals, 100 to 300 per cent. Since the scurvy animals were losing weight, perhaps we should know the effect of age on the adrenals and compare animals of the same age rather than the same weight. At present, the weight of the adrenals cannot be taken alone as an index of scurvy.

IX. DISCUSSION

That the teeth are important factors in systemic disease has long been supposed. More than fifty years ago, some physicians advocated extraction of teeth, in pyorrhea or root infection, in the hope of curing rheumatism. A method of preventing disease of the teeth would certainly be preferable. One of us has produced in white rats what he believes to be rickets, and intends to study the effects of rickets and other deficiency diseases on the teeth.

That diet may affect the teeth was suggested to one of us by his personal history. He had perfectly sound teeth until all of a sudden, following several years of malnutrition, all of his erupted molars became carious. His dietary peculiarities, as far as it is now possible to ascertain, were the following: He was a breast-fed infant and showed no serious nutritional disturbance until his fourteenth year, when his diet for over three months consisted principally of watermelons, syrup and corn (maize). This was followed by three months in bed with great weakness, gastric disturbances, tachycardia, loss of weight, loss of appetite, and mental depression. The next year a mild relapse occurred. In his sixteenth year he subsisted for three months on a diet consisting largely of cereals and syrup—of low caloric value—and lost 50 per cent of his body-weight, and experienced recurrence of previous symptoms. Mild recurrences occurred almost annually afterwards until his nineteenth year, when all his erupted molars became carious. This history may resemble that of pellagra but it suggested a dependence of the condition of the teeth on the quality of the diet. There seem to be many cases of malnutrition that cannot be classified, or whose exact nature is unknown (such as acrodynia, pellagra-sine-pellagra, and sprue).

We have shown that there is a rapid loss of calcium from the body of guinea pigs in scurvy. That bases are lost from the body is sug-

gested by the unpublished work of O. J. Engstrand. Rabbits were divided into two lots. The first lot was fed on alfalfa hay and the second on fresh alfalfa. After several months had passed and no severe symptoms of scurvy appeared, the diet of the second lot was changed to oats and of the first lot to autoclaved oats. The alkaline reserve of the blood plasma of the animals on oats was 0.019N, 0.019N, and 0.019N, respectively; and of those on autoclaved oats, 0.012N, 0.011N, and 0.011N, respectively. Since autoclaving is destructive for antiscorbutics, and the rabbits on autoclaved oats had been fed a long time previously on dry alfalfa, these animals received a smaller amount of antiscorbutics than the rabbits on oats that had previously been fed fresh alfalfa. The only question that arises is whether the rabbits on autoclaved oats became more excited when blood was drawn and breathed harder, thus lowering the alkaline reserve of the plasma.

We have shown that an acid-forming diet (that was also a scorbutic diet) caused a lowering of the alkaline reserve of the saliva in man. Since the alkali of the saliva is instrumental in neutralizing lactic acid that may be formed in the mouth, this observation, together with those on the pH required for solution of apatite, may be of some significance in regard to the preservation of the teeth.

As to the significance of the filling up of the pulp cavity of the tooth with bone (osteodentine), we are somewhat in doubt and are continuing the study of the subject. One might attempt an analogy with the process of healing of a fracture in bone. If there is slight movement at the point of fracture, the formation of new bone is stimulated. The slightly increased movement of the tooth in its socket as it begins to loosen in scurvy might stimulate the formation of bone, in this case in the pulp cavity. Osteodentine is said to be formed in the pulp cavity of teeth as a result of trauma.

The experiments on calcium metabolism indicate that the guinea pig rapidly loses calcium continuously after being on a scorbutic diet for two weeks, although clinical symptoms of scurvy are not very marked before the third or fourth week. This result suggests that one may suffer from the effects of a scorbutic diet without showing the characteristic symptoms of scurvy. Therefore, in order to maintain our teeth in good condition, we should make sure that our diet

contains sufficient antiscorbutic. As data showing the quantity of meat necessary to prevent human scurvy is not available, and as the antiscorbutic properties of most vegetables seem to be destroyed by canning, we should depend largely for our winter supply of antiscorbutic on cold storage vegetables and fruits, on canned fruits, tomatoes and rhubarb, and on dried fruits and fruit juices. Our experiments suggest that hot-pack is preferable to cold-pack, or to preservation by boiling down with sugar, due to the shorter period of exposure to the heat or to the lower temperature.

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THE OCCURRENCE OF HEMOLYTIC STREPTOCOCCI ABOUT THE TEETH

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I. INTRODUCTION

Various investigators have shown that hemolytic streptococci occur in the normal as well as in the pathological oral cavity and upper respiratory tract. The object of the research recorded here was to determine more specifically the frequency in occurrence of various hemolytic streptococci about the teeth and gums in apparently normal, and also in pathological, cases.

Literature

Davis (4, 6) has shown that hemolytic streptococci occur in the crypts of the tonsils practically constantly, and upon the surface of 60 per cent of all tonsils. Maclay (20) found, in two hundred and sixty-eight cases, fourteen strains of hemolytic streptococci in the crypts of tonsils. His examinations show a marked seasonal variation, streptococci occurring less frequently in the summer months than in the winter. Voight (27) found that 30 per cent of all cases of severe infection of the middle ear, ethmoids, and mastoids, are due to hemolytic streptococci and that these organisms occur in 80 per cent of the number of removed tonsils. He has isolated hemolytic streptococci from the urine of patients suffering from acute

tonsillitis. Nichols and Bryan (21) have shown that a high percentage of their tonsil infections is due to these streptococci, and confirm Davis' (5) observations that streptococci may occur in great numbers in the crypts of tonsils, even when surface smears fail to reveal the organisms. Henrici and Hartzell (13) believe that mouth streptococci are the true parasitic organisms of the mouth, because these are the only organisms that can live on the clean mucous membrane before eruption of the teeth. They observed that there is a relative decrease, but an absolute increase, of these streptococci in conditions of oral uncleanliness and dental decay. Henrici and Hartzell also believe that the organisms in question are the cause of dental caries, pulpitis, and pyorrhea alveolaris for the following reasons: (1) Mouth streptococci are the only organisms in these lesions that are pathogenic, as exhibited by their local invasive power, by their ability to invade the blood and lymph streams, and by their tendency to produce metastatic infection. (2) They are the only organisms found in the deep advancing borders of infected tissue. (3) In metastatic abscesses, and in experimental inoculation of animals, these organisms produce subacute and granulomatous lesions similar to the inflammatory reaction found in pyorrhea and chronic apical abscesses. (4) The true mouth streptococcus (Strep. salivarius), which, according to Holman's classification, is of the non-hemolytic variety, invades the dental pulp and peridental tissue. In a later work, Henrici and Hartzell (12) have frequently found hemolytic and non-hemolytic streptococci in dental pulps in cases of both dental caries and pyorrhea.

That streptococci are exciting factors in the etiology of many mouth lesions, and that in the oral cavity they occur as active foci of infection responsible for many systemic conditions, has been further established by Rosenow (23), Babcock (1), Lescohier (19), Eldridge (9), Earl (8), Grieves (11), Potter (22), and others. Rosenow, in his extensive studies on elective localization, lays much stress upon the importance of anaerobic cultures in maintaining the elective-localization property of the bacteria.

European workers differ from the majority of American investigators as to the exciting cause of pyorrhea alveolaris. Euler (10) believes pyorrhea alveolaris is a spirochetosis, caused by the "spiro-

cheta pyorrhica" and influenced in some way by B. fusiformis, which is normally present in the mouth, but is not pathogenic unless abundant. Intensive arsenical (salvarsan) treatment with proper oral hygiene often induces beneficial results. Dufourmentel and Frisson (7) reported three cases of mouth injuries resulting in (a) hypertoxic cellulitis of the neck, (b) phlebitis of systemic cranial facial veins, and (c) septicemia with no anatomic change. They recovered a long anaerobic bacillus, similar to the B. bellonenses of Sacquepee, that produced fatal edematous septicemia in guinea pigs. They apparently did not find hemolytic streptococci in these cases.

From a review of the above mentioned literature, it is noted that no work has been done on the occurrence of hemolytic streptococci about the teeth and gums.

II. EXPERIMENTAL

Collection of material

Cultures were obtained from one hundred and forty-four dispensary and hospital patients in the following manner. At the time of collecting the material from these patients, the presence or absence of pyorrhea and gingivitis, the general condition of the teeth, and, wherever possible, the clinical diagnosis, were noted and recorded.

Wooden applicators were sharpened to a fine point and sterilized with steam. Five-millimeter glass tubing was cut into pieces fourteen centimeters long, and one end sealed. These tubes were then half-filled with ordinary dextrose broth, the wooden applicators inserted and the tubes sealed with cotton plugs. These tubes were then sterilized twice in an autoclave.

The sharpened end of the wooden applicator was then inserted into the space between the tooth and the adjacent free margin of the gum. Here one can, in nearly all cases, obtain a large amount of septic debris that clings to the end of the sharpened point of the applicator. The gums were in no case injured in obtaining such material, as the fine pointed end of the wooden applicator was softened by the broth. For this reason it could be inserted quite deeply into the dento-gingival space; and its use is, therefore, considered more practicable than that of a platinum needle which, when similarly employed, invariably produces pain and bleeding.

After the wooden point had been deeply inserted between the gum and tooth, it was replaced in the glass container half-filled with nutrient broth, and the tube incubated at 37°C. for eighteen hours. Then sub-cultures were made from the broth.

Method of culturing

Serum broth and blood-agar plates were inoculated from the initial broth cultures. Only colonies with hemolytic zones were examined, and from these the hemolytic streptococci were isolated and studied.

The growth of hemolytic streptococci in no instance was very abundant; often there were only two or three colonies upon the plates where a loopful of the initial broth culture was made (18-hr.). Thus, the cultures differ markedly from those made with material from the crypts of tonsils, which in most cases gives an almost pure culture of hemolytic streptococci and often in large numbers.

Of one hundred and forty-four patients examined, twenty-eight (19.4 per cent) were positive for hemolytic streptococci. Twenty-nine strains were isolated, two distinctly different strains having been obtained in one of these patients. One strain fermented mannite but neither lactose nor salicin, while the other fermented lactose but neither mannite nor salicin.

Initial smears were made and studied for the first fifty cases, but this method of examination proved unreliable and unsatisfactory, and hence was discontinued.

Morphology

The twenty-nine strains obtained from one hundred and forty-four patients were isolated in pure culture and studied. After the blood-agar plates had been incubated at 37°C. for twenty-four hours, the colonies of hemolytic streptococci were removed with a wire loop, and blood-agar slants and tubes of serum broth inoculated. Smears were made from the 24-hour serum-broth cultures, and the morphology of the organisms observed. The organisms are round cocci about one micron or less in diameter, arranged in chain formation, and vary slightly in size. Often they occur singly. Frequently the cocci

appear pressed together, especially in blood-agar cultures. Lance-shaped cocci have been seen. These are smaller than the typical pneumococci and without a definite capsule. All strains stain well with the ordinary dyes and are Gram-positive.

Classification by fermentation tests

The twenty-nine strains of hemolytic streptococci (representing twenty-eight positive cases) were classified according to the fermentation reactions advocated by Holman (14). After inoculating infusion broth with B. coli, it was incubated for forty-eight hours, sterilized on two alternate days in an autoclave, and then filtered through cotton. To separate portions of this sugar-free broth, lactose, mannite, and salicin were added, respectively. This broth was then tubed, litmus added and the contents sterilized. Tubes of each kind were inoculated with each of the twenty-nine strains of the organisms and 1 cc. of blood serum added to each.

There were seventeen strains of Streptococcus anginosus. This organism hemolyses blood and ferments lactose, but does not ferment mannite, salicin or inulin. Holman found this organism prevalent in nose and throat infections, especially in scarlatinal and measles throats. The organism has also been found in endocarditis.

Five strains of Streptococcus subacidus were isolated. These are hemolytic but do not ferment any of the carbohydrates mentioned. These, too, are often found in the throat; also in joint and mastoid infections.

Streptococcus hemolyticus-I was present in three cases. This streptococcus induces hemolysis, and ferments lactose and mannite, but not salicin. It is a comparatively rare strain.

There were two strains of Streptococcus pyogenes. This organism hemolyses blood and ferments lactose and salicin. This strain of hemolytic streptococcus is also frequently associated with throat infections. It is the common hemolytic streptococcus found in pyogenic conditions where the streptococcus is the exciting etiological factor.

Streptococcus hemolyticus-II was not found. Streptococcus hemolyticus-III was found in one instance; it is a hemolytic streptococcus

that ferments only mannite. Holman found it in empyema and in the blood of puerperal sepsis.

One strain of Streptococcus infrequens was found. It is a hemolytic streptococcus that ferments lactose, mannite, and salicin. This is also a comparatively rare organism and is usually found in throat conditions. Ruediger (25) isolated it from otitis media, pericardial fluid, suppurative adenitis and conjunctivitis. Holman describes a case of chronic arthritis where this streptococcus was harbored in the tonsils and, after removal of the tonsils, the symptoms improved.

The hemolytic Streptococcus equi was not found among the twenty-nine strains.

Virulence

Generally, the virulence of hemolytic streptococci varies considerably. Passage through animals increases the virulence, while continued growth on artificial media reduces the virulence. The cell substance possesses little toxicity (16). The cells yield a streptolysin that hemolyses blood cells—a true toxin containing a haptophore and a toxophore group, and which, upon injection, produces specific antibodies (24, 2). This hemolytic substance, however, is not the dangerous endotoxin of the streptococci. In 1918, Clark and Felton (3) produced a filterable, non-hemolytic, toxic product from hemolytic streptococci which killed rabbits in doses of 0.5 cc. per 1000 grams of body-weight of the rabbit. This work has not been confirmed.

In my own tests, eleven rabbits were each injected intravenously with 2 cc. of 24-hour serum-broth cultures of the hemolytic streptococci. These were selected at random. Of the eleven strains injected, two proved to be fatal. One of the rabbits died four days after inoculation. The lung was found hemorrhagic; otherwise there was no anatomical change. The organisms were not recovered from the body fluids, a result that is believed to be due to faulty incubation. A second rabbit died ten days after injection of the organisms. There were no swollen joints; the lung was hemorrhagic and the organism was recovered from the heart blood and bile, but not from any joint. Nine of the rabbits remained alive, showing no ill effects with one exception. This one, injected with a strain of Streptococcus pyogenes, had distinctly swollen and painful joints.

Thus, only two strains were fatal to the rabbits. The pathogenicity of hemolytic streptococcus is variable for different animals. Rabbits and mice as a rule are quite susceptible. It is known, however, that strains of streptococcus after being passed through one animal, thus increasing the virulence, may not be so highly virulent for another species (17). Some varieties of hemolytic streptococcus (those often found in mastitis in cows) may be low in virulence for rabbits, although the organisms themselves are markedly hemolytic (15). Animal tests may not, therefore, be a reliable index of the virulence or pathogenicity for man.

III. DISCUSSION

It has frequently been shown that hemolytic streptococci occur in various parts of the body, e.g., upon the tonsils, in the crypts of the tonsils (4), on the hairy parts of the bodies of filthy individuals (26), in the ethmoid and mastoid cells (27), in carious teeth and apical abscess (12, 13), in the appendix (18), and in various other localities without producing acute clinical manifestations. In other words, these localities may be considered as frequent habitats for hemolytic streptococci.

Because of the fact that the space between the gingivae and the teeth is anatomically suitable for the collection of debris, and in the light of the above experimental data, it is reasonable to suppose that the gingival space may occasionally act as a focus of infection. In the one hundred and forty-four cases examined, fewer hemolytic streptococci were found about the teeth and gums to which a toothbrush had been recently applied. The majority of these cases were dispensary and Cook County Hospital patients, most of whom were grossly negligent concerning oral hygiene. Henrici and Hartzell believe, as was previously mentioned, that the "mouth" streptococci produce, in metastatic infections and in experimentally inoculated animals, subacute and granulomatous lesions similar to the inflammatory reactions seen in pyorrhea and chronic apical abscesses. This may account for the fact that the strains of streptococci injected into the series of eleven rabbits referred to above were fatal in only two cases. The virulence of the twenty-nine strains of hemolytic strepto-

cocci recorded here does not appear to be as high as that of the hemolytic streptococci harbored in the crypts of tonsils, in the adenoids, and upon the pharyngeal mucous membrane. The latter are often highly virulent organisms. The possibility that some of the organisms from the crypts of the tonsils, or from the pharyngeal mucous membrane, ordinarily are dislodged and subsequently find their way to the gingival spaces, to reside there merely as transients, must, of course, be considered. If this were true, the decreased virulence might be explained.

In the one hundred and forty-four patients examined, nineteen, or 13.1 per cent, showed distinct clinical manifestations of pyorrhea. Of these, seven, or 36.8 per cent, gave positive cultures for hemolytic streptococci. Three were of the subacidus, and four were of the anginosus, varieties. Many of these individuals had other clinical manifestations, but it should be remembered that the majority were hospital cases.

Because of the great invasive power of the hemolytic streptococci, it is highly probable that they can penetrate not only the fibrous gingivae, but also the alveolar periosteum. Here they may be taken up by the numerous lymph vessels and thence carried into the blood stream, producing metastatic lesions elsewhere. There is certainly a possibility that from this favorable habitat, in deep dento-gingival spaces, the various hemolytic streptococci may act as secondary and terminal invaders.

IV. SUMMARY OF CONCLUSIONS

The method of obtaining material for examination from gingival spaces, as described, is advantageous because it is a clean, painless procedure, and does not cause hemorrhage.

The data presented show that 19.4 per cent of a series of one hundred and forty-four patients gave positive cultures of hemolytic streptococci in material taken from dento-gingival spaces.

Of the patients with well-defined clinical manifestations of pyorrhea, 31.1 per cent gave positive cultures of hemolytic streptococci. Of the latter, three strains were of the S. subacidus, and four strains were of the S. anginosus, groups.

Hemolytic streptococci were found between the teeth and gums in three out of fifteen cases of gingivitis.

Of the various isolated strains of hemolytic streptococci, seventeen were Streptococcus anginosus; five, Streptococcus subacidus; three, S. hemolyticus-I; two, S. pyogenes; one, S. infrequens; and one, S. hemolyticus-III.

Of eleven strains, selected at random from twenty-nine strains of hemolytic streptococci isolated from gingival spaces, two proved to be fatal to rabbits in doses of 2 cc. of a broth culture. Both strains were of the anginosus type.

Because of the occurrence of hemolytic streptococci in deep dento-gingival spaces, these spaces may be considered to be potentially dangerous foci of infection.

There is a possibility that these organisms may, proceeding from the above mentioned site, act as secondary and terminal invaders.

The fact that hemolytic streptococci were found in only a small proportion of the number of cases of pyorrhea examined, and in these not in great numbers, indicates that hemolytic streptococcus is not the primary etiological factor in this condition.

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PROGRESSIVE DENTISTRY AND STOMATOLOGY

6. Periodontoclasia: Etiology, Diagnosis and Treatment[1]

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I. INTRODUCTION

Broadly speaking, the tissues of the mouth are subject to two main pathologic processes. One has its inception in caries of the teeth and leads to the death of the pulp, with infection of the periapical tissues as its final stage. The other is a disease process that attacks the investing structures of the teeth, tending toward their complete disintegration. The latter process consists of a group of diseases of greater prevalence, and has been credited with causing greater loss of teeth than the former. And while, in the past, the latter process has baffled the efforts of many in the dental profession, it is nevertheless the easier of the two to control, when once its diagnosis, etiology and treatment are fully understood.

No field of dental science has produced so many and so widely different theories, as has the study of periodontology. These theories, together with the misunderstanding regarding principles involved, have produced a condition of confusion that might be compared to

[1] The five preceding units in this series of reviews were published in the *Journal of Dental Research* by (1) Gies, i (1919), p. 525; (2) Merritt, ii (1920), p. 77; (3) Novitzky, ii, p. 567; (4) Rhein, ii, p. 579; and (5) Novitzky, ii, p. 585.—(Ed.)

that obtaining in the Tower of Babel. The reason for these puzzling differences, in points of view, is the extreme subtility and complexity of the phenomena concerned in the etiology and pathology of periodontal disease.

That the factors in etiology combine to produce a certain pathological picture in one mouth, while an apparently similar grouping seems to create a dissimilar effect in another, is almost inexplicable to the casual student. With the exception of traumatic occlusion, the factors of periclasial etiology have been known for many years. Various groupings of these factors have been suggested, with the emphasis first upon this, then upon that. The results of treatment based upon these theories have always been inconsistent. With the discovery and wide acceptance of the fact that traumatic occlusion played a part, and an important one in etiology, it became possible to explain a large percentage of earlier failures. And with its discovery also, the other factors began to assemble themselves in their true perspective in the picture.

It has been the misfortune of many clinicians to discover some part of the truth and to be so carried away with its importance as to have their view of the basic principles of periodontology perceptibly distorted. But the findings of Riggs demonstrated the part played by calculus in the etiology of periclasia, a discovery whose influence is as potent today as it was sixty years ago. Since the rôle taken by calculus was, however, but a part of the whole play of forces, it became necessary to look for other factors. Briefly, this led to the formulation of several theories, among which were the "gouty diathesis" and the "bacterial," with hopes set upon the value of antilithics, germicides and vaccines. Later developments in the realm of instrumentation carried the tide again toward the consideration of the mechanical element in etiology. The theory that mechanical irritants are the important ones, has a sound basis in pathology. For the pathologist places disturbance of function well to the fore in the etiology of disease. And the teeth, whose function is primarily mechanical, exhibit a marked reaction to mechanical irritants, and to mechanical incoördination most of all. The soundness of this reasoning is based upon the finding that most cases of periodontoclasia are essentially inflammations, and that inflammations are produced by mechanical as well as chemical and bacterial injurious agents.

The etiology and pathology of inflammations elsewhere in the body have been studied, and their fundamental facts have been recorded and accepted. The facts which produce an inflammation of the periodontium are precisely those which produce other inflammations, just as the changes which take place in the periodontium as the result of inflammation are similar to those occurring in other inflammatory processes.

Recent study of the histology of both the tooth and its investing structures, justifies the assumption of an optimistic attitude toward the treatment of dental periclasia. Clinicians for many years have maintained the fundamental possibilities in treatment, notwithstanding the fact that eminent histo-pathologists have assured them that the results which they observed were scientifically impossible. With the additional evidence of the latest researches in histology, we can confidently announce the confirmation of the claims of Riggs made half a century ago. Thus, the responsibility of the dentist, in this field of practice, becomes at once an issue which may not be evaded.

II. ETIOLOGY

There is no more disputed point in the consideration of periclasia than the etiology of this group of disease processes. The difficulty has arisen from the variety of causes concerned, together with the natural effort to establish the culpability of some one supposedly universal factor. Workers in this field of investigation are often led by their observations to make statements concerning the etiology of periclasia, which may be true of the case or cases under observation, but which are nevertheless quite untrue when they are applied to the whole subject. When one observer publishes a statement that this particular factor is the cause of *all* periodontal disease, while another observer of equal ability asserts that an entirely different factor is the cause of *all* periclasia, it is safe to assume that at least one of them has been misled.

Consideration of the facts of etiology demands, first, that we take a birds-eye-view of the entire field, for in this way only can we assign to each factor or group of factors its proper place in the perspective of the picture. The causes of periclasia are many, and they are

found in an almost endless variety of combinations. Yet they may be so classified as to make periclasial etiology readily comprehensible. Before proceeding, it will be well to state three fundamental hypotheses.

(1) The first hypothesis regarding etiology may be stated as follows: The causes of periodontoclasia are primary or inaugurating, and secondary or non-inaugurating. While this division corresponds quite closely to the previously accepted division of the causes of disease into predisposing and exciting, there is a distinction. In the latter mode of classification the important cause is the exciting cause, while the predisposing cause may often be relatively unimportant, difficult to locate, and in some cases may have little bearing on the treatment of the disease. In periodontoclasia, on the other hand, the primary cause is always the inaugurating one, in the sense that without it periodontal disease does not occur. And it is almost invariably the most important factor from the standpoint of treatment. This statement is so fundamental that it will bear reiteration. For not only has our profession, in the past, sought a single specific cause for a single disease, but it has focused its attention on the treatment of secondary causes, of which infection is usually the most obvious. It is of course a matter of common observation among periodontists that treatment of infection, lowered tissue resistance, and other secondary causes, by medication, etc., has never been successful. Nor will such treatment ever give satisfactory results unless the primary causes which render infection possible are first removed.

(2) The second hypothesis may be stated as follows: The etiology of any one case of periclasia consists of at least two factors. In other words, no single etiological factor will inaugurate any form of periodontoclasia. This statement is so important as to require elaboration. Let us take, as an instance, the suppurative types of periodontoclasia. It is a fact, well understood, that susceptibility to infection depends primarily on lowered resistance in the tissue attacked. In order that infection of the periodontal tissues may take place, the resisting powers of their cells and intercellular fluids must be lowered to a point where they are unable to repel and destroy invading bacteria. This lowering of resistance is brought about through the

operation of one or more agencies, which, because of the essential part they play in this process, we call primary factors. For only after tissue depression has taken place do we note the activities of the pyogenic bacteria, which constitute the secondary cause. And so, for practically every type of periclasia in which infection plays a part, we have at least two etiological factors; namely, a primary mechanical injury with accompanying depression, and a secondary bacterial invasion.

Note must here be made of a very important exception to this statement. It occurs in cases of congenital non-occlusion cases in which, as a result of mal-occlusion, certain teeth have never had occlusal contact with their antagonists. Such cases bear out the hypothesis as regards the sequence of lowered resistance and bacterial invasion. But they differ from the average inflammatory case in the source of their lowered vitality. This lies in their entire absence of function, rather than in the adhesion of foreign matter to the tooth surface. Hard and soft deposits do constitute a true mechanical irritant, but the extent of the lesions found in such cases is out of all proportion to the amount of deposit found.

The primary factors are the important ones. Yet the suppurative types of disease cannot be produced by these primary factors alone, since certain of the type characteristics can be produced only by bacteria and their toxins. Even in the types which exhibit no microscopic evidence of bacterial invasion, the same hypothesis holds true. Primary factors do not produce disease or loss of tissue without the concomitant action of secondary factors, such as functional insufficiency, frail osseous support, etc., together with bacterial activity.

The plural character of periclasial etiology may also be exemplified in phenomena frequently observed in this group of diseases. Salivary calculus is frequently found in mouths which appear to be free from disease, thereby apparently eliminating it as a causative factor. Pathogenic bacteria may also be found in healthy mouths, and hence seem to be eliminated as a cause of periclasia. Even traumatic occlusion is occasionally found in a mouth in which no disease is to be discovered. But, if traumatic occlusion be combined with lowered tissue-tone, calcareous deposits and bacterial invasion, a suppurative pericementoclasia is the inevitable sequel.

(3) The third hypothesis concerning periclasial etiology may be stated as follows: The inception and course of periodontal disease are equally under the control of biogenetic and pathogenic forces. A point which has baffled many observers, even those who have appreciated the plural character of periclasial etiology, is the fact that a patient may present a practically healthy mouth, in which there is, nevertheless, a grouping of factors which apparently should produce periodontal disease. To have disease, however, it is not enough that pathogenic agencies be introduced; these we have about us at all times. Disease can only be inaugurated when the pathogenic forces overbalance the biogenetic, either by their own noxious activity, or by the ebbing of the vital forces. There is a balance between the anabolic and catabolic whose adjustment is as delicate as that of a pair of scales. And we may often, as with the scales, preserve a threatened equilibrium by the introduction of biogenetic factors to counterbalance the continued and unrelieved presence of pathogenic forces. These biogenetic forces are the heritage from past generations or are developed as the result of a return to the conditions of function which nature demands.

III. DIAGNOSIS

Diagnosis is the foundation of treatment. It is the recognition of the fact that a disease process exists, and it designates the nature of the process. But diagnosis implies more than the recognition and delimitation of the pathological condition; it implies, as well, a determination of the etiological elements involved. This apparently two-fold meaning of the word "diagnosis," namely the determination of the nature and of the causes of disease, must be kept in mind, for this fact is to the clinician what the chart and compass are to the mariner. If the mariner sets out to sea without the necessary instruments of navigation, he soon is lost and knows not in which direction to proceed. Applied to the treatment of human disease, the methods of the careless and incompetent mariner become nothing more or less than plain malpractice.

Recognition of many types of periodontal disease is so simple, that when present, the disease is obvious even to the lay observer. Unfortunately the dentist is frequently oblivious to its existence,

until an anxious patient intrudes the evidence of its presence upon his consciousness. The reason for this apathy may lie in a series of unsuccessful empirical attempts to control these disorders. With what reluctance does the small boy drag himself to his first party, for the reason, no doubt, that he senses his deficiency in the social art. So, too, the dentist.

But the dentist, while capable of discovering early signs of oral disease, has been lost in the maze of conflicting opinions regarding the nature of periodontoclasia, its etiology and its treatment. Moreover, some of the textbooks dealing with this subject, under such titles as "pyorrhea alveolaris," "interstitial gingivitis," "phagedenic pericementitis," "suppurative pericementitis," "peridentitis," etc., have assumed a distinctly pessimistic attitude toward the prognosis of these disease processes. In the light of this attitude, as expressed by the recognized authorities, it is small wonder that the practitioner has developed a frame of mind the result of which is that he not only hesitates to treat these conditions, but closes his eyes to their very existence.

Ability to diagnose periodontal disease has developed very slowly and painfully. In the days of Riggs there was no diagnosis which was worthy of the name. With the gradual development in the art of periodontia, treatment has consistently led diagnosis. In other words. empirical treatment has produced results which have, by inverse reasoning, served to point out the nature and cause of the disease process. Advances in the methods of treatment have revealed the significance of pathological and etiological factors, through which the further development of diagnosis has followed. Each advance in diagnosis has been brought about by the earnest study of previously inexplicable failures. Each difficulty, when surmounted, has proven a stepping-stone to the solution of the next problem.

Strange to say, the microscope, which ushered in the era of modern pathology, as exemplified in the study of antiseptics and the antibodies of living tissues, diverted the forces of periodontic investigation into hopeful but unproductive channels. For, while the phenomena of the breaking down and repair of periodontal tissue can only be fully understood through the revelations of the microscope, it is nevertheless true that the bacteriological explanation of these phe-

nomena constitutes but a chapter of the story. Students of inflammatory processes distinctly state that these changes may be brought about by mechanical, chemical or bacterial irritants. But the enthusiasm over the discovery of the bacterial element in disease has blinded dental investigators to the coexistence of all three forms of irritation in disease of the periodontium. The forces of repair, no matter how stimulated, can never successfully combat mechanical irritation when the method of treatment is aimed chiefly at bacterial irritants. Diagnosis therefore, to be complete, must take into account *all of the factors* of disease and its causation, and assign to each its proper valuation in the group.

Diagnosis of advanced periodontoclasia is simple, because of the obvious breaking down of the tissues which support the teeth. At this period diagnosis has little practical value, of course, for the reason that, when the condition has reached an advanced stage, repair is usually beyond the power of the organism.

The early recognition of the symptoms of periclasia is more difficult, yet the dentist must bend his energy toward their recognition at the earliest possible moment, and for two very cogent reasons. The first lies in the obvious advantage occurring to the patient, when the condition is discovered before a considerable dissolution of the supporting structures has taken place. The other has to do with the difficult technique and varied instrumentation required for the root surgery of advanced cases. In other words, the average incipient case will be within the diagnostic powers of the competent general practitioner. It will not demand a skill in treatment beyond his ability to acquire, nor will it require a very large assortment of instruments in its treatment. The field of the general practitioner lies in the treatment of incipient cases. When he is dealing with lesions exhibiting a pocket-depth of more than 3 mm., his chances of success begin to dwindle very rapidly. This assertion is made as a result of experience gained in handling many such cases. It might be added that only through such experience can one come to a full realization of the requirements of natural aptitude, exacting technique and variety of instruments, which the treatment of advanced cases demands.

To detect the presence of most disease conditions of the gingival tissues, then, is simple to the point of absurdity. It requires only a careful ocular examination, supplemented by exploration under the gingival margin with a slender blunt probe. Differential diagnosis of the types of periodontoclasia and the determination of their etiology is not so simple. Yet even here careful study will enable the conscientious dentist correctly to diagnose most of the cases that come under his observation.

Given a knowledge of the types of periclasia and their etiology, the next requirement in diagnosis as well as in treatment is optimism. The dentist, when making an examination for the presence of gingival disease, must not dread to find it, or he will inevitably blind himself to the first faint signs. To ignore the incipient is to endanger not only the health of the periodontal tissues, but the general health of his patient. And each of these comes within his province to preserve. He should approach his patient with that optimism which comes with a broad knowledge of dental service, and this includes the knowledge that periodontal disease can be cured and can be prevented.

Examination and diagnosis of oral disease can only be complete when the condition of the rest of the body is also determined. It may be stated as a truism that disease in any one part of the body has a more or less perceptible effect on the entire organism. It therefore follows that disease in the mouth produces reactions in other parts of the body, and that extra-oral pathological changes likewise produce definite effects in the mouth. For these reasons, oral examinations, to be complete and to reveal all the aberrations of the individual as they pertain to the oral condition, should include records of the family and personal history and of the subjective symptoms, and examinations of the eyes, nose, throat, the gastro-enteron, genito-urinary system, heart, lungs, blood, nervous system, etc. Modern medicine regards an examination of the mouth, and of the teeth particularly, as essential to a complete physical diagnosis.

It is obviously impossible for a dentist, or for any other specialist in medicine for that matter, to make all of the required examinations or to adjudicate the records. While the dentist may acquire the knowledge and ability to make such tests as those of blood-pressure, blood-count, urinalysis, and some of the simpler bacteriological

examinations, etc., it is not good practice for him to make these examinations. The danger of such a proceeding lies in the probability, and even the certainty, that other tests equally important will not be made. This is due to the natural tendency to rely on those tests which he regards as necessary, and with whose technique he is familiar. This tendency to incomplete diagnosis is also recognized in the practice of medicine as being the basic reason for improper treatment. For it is acknowledged that all correct treatment must be based upon exact diagnosis. The dentist, while he should be familiar with the various diagnostic tests, and with the symptoms which make it advisable to recommend them, renders his patients the best service by referring them to the medical internist for all extra-oral diagnosis.

From the standpoint of the periodontist, general physical diagnosis, while valuable and desirable as an aid in the diagnosis of the mouth conditions, is not always essential. The reason for this lies in the etiology of periodontal disease. Nevertheless, all the factors concerned in general and oral health, and the mechanical maintenance of function, are equally important to the patient. They should all receive consideration in the formulation of a correct diagnosis.

The first step in making a diagnosis of a case should be the recording of the clinical findings upon a standardized chart. It should include the following:

(1) Complete radiographic examination.

(2) Tests of vitality and health of the pulp (electric, thermal, transillumination).

(3) Study casts (standard orthodontic).

(4) Clinical examination of the teeth and periodontium.

(5) Case history (dental).

(6) Prognosis (local and systemic).

All of this data should be carefully recorded on a chart and the complete examination of the case given sufficient study prior to operative procedure, the relief of pain being the one exception. As the treatment of the case progresses, notation is made of any changes in the condition of the tissues which may occur. Indications for the treatment of cases are based upon the evidence revealed in the examination.

The first consideration of the dental diagnostician is the general health of the patient. Teeth, which by the evidence of their history, and the clinical and radiographic examinations, seem to be hopelessly infected and diseased should be recommended for extraction without compromise. Since teeth with coincidental periapical and periodontal infections have a poor prognosis, opicoectomy is not to be recommended in such cases. The desirability of retaining teeth, for the single reason of their strategic importance in the making of restorations, should not be allowed to influence the judgment of the operator, if their individual prognosis is negative. The prognosis with reference to teeth whose extraction is not demanded by reason of the foregoing considerations, is then to be determined.

The diseases originating outside of the mouth, which produce the most marked reactions in the mouth, may here be enumerated. The most important systemic pathological conditions that may complicate periodontoclasia, are those which originate in an enteric toxemia. These and their reflected gastric disturbances frequently influence profoundly the course of periodontal disease. These and nephritic disorders, disturbances of the central nervous system and lactic infections, produce the most marked changes in the previously deranged periodontium. The previously healthy periodontium reacts but slightly if at all to these conditions. Given an established or concomitant pathological condition of the periodontium, however, the presence of any of the conditions enumerated above will increase the severity and rapidity of the disease, but does not preclude the possibility of securing successful results in treatment.

IV. TREATMENT

Treatment of periodontoclasia is in no way different, in principle, from the treatment of other infectional inflammatory disease conditions. Correct pathological and differential diagnosis is within the ability of the sincerely interested dentist. The pathology of the various types of periodontal disease is fundamentally that of other inflammatory processes, with such modifications as are brought about by the nature and location of the tissues involved. Etiology, while complex, is made up of factors which, for the most part, may be readily

determined by the clinician. It only remains to assign to each case that group of factors which are responsible for its development. These things once determined, treatment follows as a matter of course. When the periodontist recognizes that which needs to be done, he soon acquires the ability to do it. For it is a conspicuous attribute of those who are trained in dental technique, that what the brain conceives the hand is able to create. But it goes without saying that the product of the hand furnishes a measure of the professional quality of the man.

It cannot be emphasized too strongly that successful treatment of periclasia must be based absolutely upon correct diagnosis, and this in turn has its foundation firmly fixed in the determination of the correct etiology.

Our first consideration, then, is to seek a grouping of etiological factors that will permit of the laying out of a general plan of treatment, modifications of which may be readily adopted according to the individual variations in the type of disease, and their accompanying factors. It has been observed, as would naturally be expected, that certain combinations of etiological factors have a tendency to produce certain types of disease. As a corrollary, it may therefore be stated that the appearance of each type points the way to the recognition of the causes responsible for its development.

A general consideration of etiology reveals mechanical factors, lowering of tissue resistance and bacterial invasion as the usual conspicuous landmarks. Treatment, then, should be directed toward the relief of mechanical irritation, reduction of the bacterial count and stimulation of cell vitality. The correction of mechanical irritation usually demands relief from traumatic occlusion, removal of septic and necrotic accumulations on the tooth surface, the restoration of normal approximal contacts, and the normal surface contours of the teeth.

The reduction of the bacterial content of the mouth, which, in the past, has been unsuccessfully attempted by the application of chemicals, is actually attained (in chronic inflammations) by the surgical elimination of bacterial culture media from the surfaces of the teeth. This surface, like the fouled bottom of a ship, becomes host to the parasites of the mouth; its accumulation of debris furnishes

the attached bacteria a rich variety of pabulum and a unique protection, retaining them in contact with the approximating vascular tissues. It is an apparent anomaly that while the vascular structures of the periodontium are the site of the attack, and the sufferers therefrom, the invasion has its origin on the adjacent tooth surface, and is only possible because this tooth surface provides anchorage, and thereby an opportunity, for bacterial proliferation. And it is well to keep in mind that, while the object of our treatment is the relief of disease resident in the investing tissues, our remedial procedures are applied almost entirely to the tooth surface itself. It is as though one threw water upon the house with the intention of extinguishing a fire in the barn. Absurd as such a procedure would be, its apparent analogue in the treatment of periodontoclasia is founded upon scientific truth. For, as soon as the tooth surface is clean and mechanical irritation has been removed, the same sharp biogenetic reaction follows treatment as when a septic foreign body has been removed from the flesh: the former ratio between phagocytosis and bacterial proliferation is reversed, with coincidental re-establishment of normal circulation.

It is not to be denied, however, that a definite response follows instrumentation, even when incomplete. This has been attributed, by some, to the auto-vaccination that occurs when a wound is made in infected tissue. While this process does actually take place upon occasion, and probably plays its part in the response of the tissues, it should also be kept in mind that a sterile wound, in uninfected tissue, calls forth quite as sharp a reaction. The latter may be considered a physiologic response, and is particularly concerned in arousing tissue tone, a factor of the first importance in the treatment of periodontal disease.

The aim of treatment, as before stated, is to remove the factors that are responsible for the occurrence of the disease, and to give momentum to the biologic forces of repair. It must have its basis in diagnosis of the nature of the lesion and of its causative factors. The intelligent clinician will therefore decide for himself, as he studies his case, when he shall depart from the general plan of treatment, and in what direction this deviation shall proceed.

V. CONCLUDING REMARKS

In conclusion, there are two points which should be emphasized. The first relates to the value to be assigned to any type of treatment designed primarily to deal with the bacterial element in periodontoclasia. Vaccines, antiseptics, germicides and treatments intended to increase tissue resistance, are only partially successful at best, and are usually entire failures. The reason is that the bacterial element is secondary to other factors in the etiology. Control of tissue tone and of bacteria may have an effect, in many cases, for nature is accustomed to working against heavy odds and is grateful for even a little help. But any treatment not founded on a consideration of the entire etiology of the case, must inevitably fail to give that full meed of satisfaction which is the right of the patient and the joy of the periodontist.

The second point, and a most important one, is that in science, as in all life, theory must conform to fact, not fact to theory. The reason for our confidence in the truth of the theories herein presented, is that we have found these theories consistently to conform with the facts. Many theories have been advanced in the past upon which systems of treatment were built. And in nearly every case, when failures were encountered, efforts were made not toward remodeling or expansion of the theory, but toward distortion of the facts to fit the preconceived theory. It is as though a law were written to deal with certain facts, and, when it was found that other disturbing facts had a bearing on the case, the courts were to rule out the intractable facts rather than to rewrite the law in the interests of entire justice.

Cases of periodontoclasia have been diagnosed and their etiology and prognosis assigned. Treatment based on this foundation has so uniformly given the degree of success or failure which was expected, that the soundness of the proposed theories is considered to be established.

THE ORIGIN AND EVOLUTION OF THE HUMAN DENTITION

A Palæontological Review

(*Concluded*)[1]

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PART V. LATER STAGES IN THE EVOLUTION OF THE HUMAN DENTITION; WITH A FINAL SUMMARY AND A BIBLIOGRAPHY

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[1] Parts I, II, III and IV, of this review, were published successively in the quarterly issues of volume ii of the Journal of Dental Research, beginning, respectively, at pages 89, 215, 357 and 607.—(*Ed.*)

I. ORIGIN AND RISE OF MAN (SERIES CATARRHINÆ, FAMILY HOMINIDÆ)

INTRODUCTION: PRESENT DIVERSITY AND CONFUSION OF OPINION REGARDING THE ANCESTRY OF MAN

Darwin, in his immortal work on "The Descent of Man," says (p. 200): "It would be beyond my limits and quite beyond my knowledge, even to name the innumerable points of structure in which man agrees with the other Primates. Our great anatomist and philosopher, Professor Huxley, has fully discussed this subject[2] and concludes that man in all parts of his organization differs less from the higher apes than these do from the lower members of the same group. Consequently 'there is no justification for placing man in a distinct order.'" In another passage Darwin says: "Now man unquestionably belongs in his dentition, in the structure of his nostrils, and some other respects, to the Catarrhine or Old World division; nor does he resemble the Platyrrhines more closely than the Catarrhines in any characters, excepting in a few of not much importance and apparently of an adaptive nature. It is therefore against all probability that some New World species should have formerly varied and produced a man-like creature, with all the distinctive characters proper to the Old World division; losing at the same time all its own distinctive characters. There can, consequently, hardly be a doubt that man is an offshoot from the Old World Simian stem; and that, under a genealogical point of view he must be placed with the Catarrhine division" (pp. 205, 206).

Again (pp. 206–207): "If the anthropomorphous apes be admitted to form a natural sub-group, then as man agrees with them not only in all those characters which he possesses in common with the whole Catarrhine group, but in other peculiar characters, such as the absence of a tail and of callosities, and in general appearance, we *may infer that some ancient member of the anthropomorphous sub-group gave birth to man* [italics mine]. . . . . It is not probable that, through the law of analogous variation, a member of one of the other lower sub-groups should have given rise to a man-like creature, resembling

[2] Evidences as to Man's Place in Nature, 1863, p. 70, *et passim*.

the higher anthropomorphous apes in so many respects. *No doubt man, in comparison with most of his allies, has undergone an extraordinary amount of modification, chiefly in consequence of the great development of his brain and his erect position* [italics mine]; nevertheless, we should bear in mind that he 'is but one of several exceptional forms of Primates.'"[3]

During the fifty years which have elapsed since these words were first published the evidence for their exact truth has become so vast in extent that no single investigator fully understands more than a part of it. Darwin's passages quoted above seem indeed to have been lost sight of under the accumulation of details. Nevertheless all those who have succeeded in retaining a view of the field as a whole and who have not allowed themselves to be misled by minor difficulties, have always clearly perceived the truth and manifold implications of the following propositions:

1. That man is a member of the order Primates.
2. That man is an offshoot not of the platyrrhine but of the catarrhine or Old World division of the apes and monkeys.
3. That man is descended from some ancient member of the anthropomorphous sub-group of the catarrhine division.

Of course a great number of zoölogists besides Darwin, such as Linnæus, Blumenbach, Cuvier, Owen, Huxley, Haeckel, had provided the material for these generalizations, but Darwin displayed his usual skill and sagacity in synthesising the results of comparative anatomy with those of taxonomy and in deriving therefrom the most important genealogical deductions.

Now it is the universal experience of mankind that it is not enough to discover and proclaim the truth once for all. For no sooner has the truth been discovered and proclaimed than schismatics and heretics begin their destructive but inevitable analyses. If it is to survive, the truth must be defended and renewed generation after generation by those who perceive the truth. And so it is, with regard to the truths of man's taxonomic relationships and genealogical origin, as perceived by Darwin, Huxley, Haeckel, Gaudry and many others. These truths are in danger of being crowded out of sight by many "heresies."

[3] St. George Mivart: *Transactions of the Philosophical Society*, 1867, p. 410.

If any of these opposing views of man's origin is true, much of the present review of the evolution of the human dentition is worthless. But as space is lacking for a detailed examination of each one, I shall attempt only to list a few of the more important and to indicate the general nature of my objections to each.

(*1*) *The "Tarsius theory" of Wood Jones (1918), called the "new heresy of man's descent" by Pocock (1920), but really dating in essentials to Cope (1882) and Hubrecht (1897).* This hypothesis, which considers *Tarsius* as the nearest living relative of man, was discussed at length by a number of eminent anatomists and zoölogists, in a special "Symposium on *Tarsius*" in the *Proceedings of the Zoölogical Society of London*, for 1919. The consensus of their opinion was that the hypothesis is based on incorrect interpretation of relatively unimportant points of agreement between *Tarsius* and man. The hypothesis has also been considered and rejected by Gerrit S. Miller (1920) and by R. I. Pocock (1920), and it has been referred to from time to time in other parts of this review. In my opinion it rests upon a wholly incorrect analysis of the taxonomic, palæontological and anatomical evidence bearing on the evolutionary histories both of man and of *Tarsius*. In discussing the anatomical characters of man, Wood Jones shows that he does not know how to distinguish the "habitus" of more recently acquired characters, by which man is adapted to his peculiar life habits, from his "heritage," which he shares in common with the anthropoid apes. He also fails to appreciate the fact that the catarrhine or Old World series is a natural group and that man belongs with the anthropomorphous subdivision of that group. Thus he ridicules the "Linnæan system" without knowing how to make effective use of it.

(*2*) *Misapplication of the "law of polyphyletic evolution."* Adloff (1908), totally ignoring the facts of taxonomy and palæontology, gives a fanciful diagram of the supposed genealogical relationships of man and other primates, in which each group is made to run back on parallel lines which are just as far apart in earlier geological epochs as they are at present. Such parallelogenic concepts, as they may be called, must imply that the very numerous special resemblances between man and the anthropoids are wholly due to "parallelism" and "convergence," neglecting the well established principle that the

closer the parallelism the closer the relationship. Other forms of the "polyphyletic" view, while less extreme than that of Adloff, rest on the erroneous inference that because some other phyla of mammals have been shown to run far back into the Lower Tertiary, therefore the human line does also. This bald "fallacy of the undistributed middle" is quite popular at the present time, especially among palæontologists, who, in their otherwise praiseworthy caution, are very apt to ignore the cumulative evidence for the relatively close relationship of man with the anthropoids.

An extreme and peculiar form of the "multiple-origin" idea has lately been produced by Sera (1917). According to his phylogenetic diagram, the group of Primates comprises many parallel offshoots from the theromorph reptiles coming down through the later ages and giving rise to different races of men, apes and monkeys, some of the phyla, however, recombining in relatively recent times! Such a concept may be acceptable to some of those who reject the whole Linnæan system of classification as a totally artificial device, but it can never be viewed seriously by those who are convinced from experience that the families of the Primates are natural groups, i.e., the diversified descendants of remote common stocks.

(*3*) ***Misapplication of the "law of the irreversibility of evolution."*** Because (a) evolution *is* irreversible in one sense, and because (b) in many wellknown cases remote ancestral forms foreshadow their highly specialized descendants, and because (c) man is evidently now widely different from the anthropoids, it is erroneously assumed that the early Tertiary ancestors of man must have been man-like. *Ergo* they must have had large foreheads, small canines, an erect posture and human feet! This view ignores the important principle of "change of function" by which human have been derived from unhuman characters. The matter is touched upon below and will be more fully dealt with in other papers.

(*4*) ***"Uniformity in the rate of evolution."*** It is often implied that the second half of the Tertiary Period (amounting perhaps to a couple of million years) is too short a time for man to have evolved from a primitive anthropoid, because during the last few thousands of years the change has been slight or negligible, and because evolution is somehow assumed to have proceeded at a uniform rate. But this

view ignores the overwhelming evidence that *rates of evolution are as variable and as specific as anatomical characters themselves.*

(5) *Misapplication of the "law of non-correlative evolution."* Balzac's famous version of Cuvier's principle of correlation is admittedly erroneous. Hoofs are not invariably associated with herbivorous dentitions. But from such facts the generalization has been drawn that there is no correlation of parts. The real fact is, however, that there are all degrees of correlation of parts from zero to 100. If we find the highly characteristic lower molars of an extinct species of anthropoid ape closely allied to the chimpanzee, there is little risk in assuming that the upper molars and even the rest of the dentition will also be more or less like the corresponding parts of a chimpanzee. And if we find that the several species of Miocene anthropoids all have less specialized teeth than those of their modern relatives, it seems conservative to assume that even the limbs were nearer to a primitive anthropoid type, always making allowances for peculiar and unexpected characters. But this is precisely the kind of inference that we are warned against by those who point to the "principle of non-correlative evolution" and who insist on waiting for "more fossils and many more fossils" before making full use of those that we have.

The present diversity and confusion of opinion regarding the problem of man's ancestry has partly resulted from the regrettable isolation and lack of coördination of research on the part of the following classes of workers:

(A) Such anatomists as have become lost in the vast field of descriptive and unphylogenetic anatomy, who do not realize that it is futile to make comparisons of the conditions represented in a few widely separated twigs on the great phylogenetic tree of the vertebrates, who do not feel the need of proceeding systematically to examine a given structure in closely related forms before passing to comparisons on a wider scale, who in a word *ignore the taxonomic positions* of the forms they have dissected; who too often ignore also the available palæontological and comparative evidence concerning the history of the forms examined.

(B) Such anthropologists as lack a practical and effective knowledge of mammalian evolution.

(C) Such palæontologists as realize too keenly the insufficiency of the palæontological evidence, but who do not realize that in many cases the evidence of taxonomy and comparative anatomy may often surely supply that which the palæontological record lacks. It is literally true that in many cases the evidence of morphology and taxonomy is complete and convincing, while the evidence of palæontology is defective. In the case of man, for instance, the taxonomic and morphologic evidence for Darwin's conclusions is overwhelming, while the palæontologic evidence is extremely imperfect. And yet palæontologists have so long asserted that the final decision must always rest with palæontology that morphologists have weakly and quite unnecessarily concurred.

(D) Such writers of semi-popular, semi-scientific articles as desire either to record something new and startling, or, with praiseworthy caution, suggest that the whole subject of man's ancestry is a "mystery" and that the most that can be safely admitted is that man is derived from some as yet wholly unknown form of Primate.

(E) Such scientists and others as are ashamed of their poor relations and are looking for more genteel ancestors than the brutal and disgusting apes.[4]

COMPARATIVE ANATOMICAL AND OTHER EVIDENCE SHOWING THE RELATIVELY CLOSE KINSHIP OF MAN WITH THE ANTHROPOID APES

For thirty years past Professor Arthur Keith, of the Royal College of Surgeons in London, has been collecting the data resulting from his own and from other investigators' observations on the comparative anatomy of anthropoid apes and man. From time to time he has assorted these observations and presented the results in numerical form (1911, 1916). Of 1065 human characters he gives 312, or about one-third, as peculiar to man, and a total of 623 shared by man with one or another of the anthropoids or with all of them together; the remaining 120 human characters are held in common either with Old World monkeys (53), with New World monkeys (60) or with lemurs (17).

[4] On this head compare Wood-Jones's remarks (1918) on the degrading effect of Darwin's theory on mankind.

These figures, especially the high number of human characters shared by man with one or more anthropoids, and the large number of peculiar human characters, are in harmony with Darwin's conclusions, "that some ancient member of the anthropomorphous subgroup gave birth to man," and that "man, in comparison with most of his allies, has undergone an extraordinary amount of modification, chiefly in consequence of the great development of his brain and his erect position." But that a mere summation of characters is not always sufficient, is fully recognized by Professor Keith and is further indicated by the fact that in the list as drawn up man has a slightly greater number of characters in common with the New World monkeys (60) than those in common with the Old World monkeys (53), to which he is undoubtedly more nearly related.

As stated above and also in Part II of this review, it is important to realize that the cænotelic or relatively recent characters of the habitus or present complex of adaptive characters, tend to conceal the more remote relationships of any given animal, while its heritage, or residuum of characters acquired in earlier stages of evolution, tends to reveal them.

In the following pages we may review briefly some of the more striking points of resemblance between man and one or more of the anthropoid apes. Of course, such a review will not be convincing to those who regard the Linnæan system of classification as wholly artificial and who believe in the almost infinite ability of "parallelism" to produce close resemblances between organisms belonging to widely different stocks. In the end all I can do is to assert again that such a concept is not compatible with a practical knowledge of mammalian evolution and to submit references to other papers[5] in which the matter is more fully discussed. Meanwhile *the anthropoid heritage of man* is revealed in the facts set forth below.

The wellknown tests of blood relationships, by means of "anti-human" and "anti-primate" sera, have been described by Nutall in his work on "Blood Immunity and Blood Relationship." In discussing the tests with anti-primate sera, Nutall says (p. 214): ". . . . The degrees of reaction obtained indicate a close relationship between the Hominidæ and Simiidæ, a more distant relationship with the Cer-

[5] Gregory: 1910, pp. 258, 463; 1920, pp. 192–193.

copithecidæ, the bloods of Cebidæ and Hapalidæ giving still smaller reactions than the last, when we consider the results obtained with the first three antisera. The tests with antiserum for *Cercopithecus* give the largest reactions with bloods of Cercopithecidæ, next with those of Hominidæ and Simiidæ but slight reactions with those of Cebidæ and Hapalidæ. All four antisera failed to produce reactions with the two bloods of Lemuridæ tested, except when sufficiently powerful also to produce reactions with other mammalian bloods. From this we may conclude that the Lemurs properly belong to an Order separate from the other Primates."

That the main physiological reactions of the great apes, especially the chimpanzee and the gorilla, closely resemble those of man is indicated not only by the blood tests above noted but also by Keith's (1899) description of menstruation in the chimpanzee; by Huntington's (1913) description of the salivary gland complex; and by Duckworth's (1915, pp. 204, 209) description of the alimentary canal of the gorilla. Convincingly human is the appearance of the pregnant female chimpanzee, and the same is true of the genitalia of both sexes of the chimpanzee and of the gorilla. The pendent breasts of old female chimpanzees and gorillas are also equally suggestive of human relationship. Retzius, quoted by Duckworth (1915, p. 210), found that with regard to the spermatozoa the gorilla is of all the primates the form most similar to man.

All modern observers testify to the elaborate and fundamental resemblances of the brains of chimpanzees and gorillas to the human type, not only in general form and position of the principal fissures and convolutions, etc. (Duckworth: 1915, pp. 188–196), but also in the arrangement of the various centers, detailed architecture of the brain-stem, etc. Professor Frederick E. Tilney, who is now engaged in a comparative study of many hundreds of serial sections of a gorilla brain-stem, has kindly informed me that the detailed construction of the brain-stem of the gorilla is extremely close to the human type.

Of course the marked differences in habits and mental capacity between men and apes are reflected in the vastly superior development of certain parts of the human brain, but modern anatomists are agreed that the difference is one of degree rather than of kind.

The search for large-brained human ancestors in early Tertiary times is based first on the too prevalent fallacy that remote ancestral stages must already foreshadow all the characters of their distant descendants, and secondly, upon naïve faith in the biogenetic law, in so far as it is inferred that the swollen brains of young stages are reminiscent of adult brain-form of ancestral stages.

As the braincase in general is only a sort of bony wrapping around the brain and its membranes, modified by crests for the jaw muscles and by specializations of the parts covering the sense organs, it is not surprising that the interior of the braincase, especially of the female chimpanzees and the gorillas, should strongly resemble the human type. This is seen not only in the general architecture of the braincase, but in such minor details as the development of sphenoid and frontal sinuses, the form of the sella turcica, and the arrangement of the foramina for the cranial nerves, arteries and veins. Even certain wellknown differences between typical human and typical anthropoid skulls, such as the squamoso-frontal contact shutting out the usual frontosphenoid contact, are occasionally bridged by low human skulls; the skulls of the extinct Neanderthal race contained several simian characters that are ordinarily lost in the higher human races, such as the small size of the mastoid process, the flatness of the glenoid eminence, the retreating chin, wide ascending ramus of the mandible, very low forehead, projecting tori orbitales, very wide nasal opening, lack of canine fossa in the superior maxilla, etc.

Especially strong evidence for the close relationship of the gorilla and chimpanzee with man is afforded by the construction of the nasal chamber (*fig. 300*). The turbinate bones, the lower, middle and upper nasal meatus, and the frontal, ethmoid and sphenoid sinuses, have substantially identical interrelations, differing chiefly in the degrees of development of certain parts, in correlation to some extent with the condition that in the ape the prepituitary portion of the braincase is not sharply bent downward as it is in man. Keith (1916) has noted that in the possession of a frontal sinus which is lacking in the orang, the chimpanzee and the gorilla agree with man. All such remarkable agreements reinforce the conclusion that the relationship of the chimpanzee-gorilla stock is relatively close to man, and that "the closer the parallelism the closer the relationship."

FIG. 300. SAGITTAL SECTIONS OF THE SKULLS OF A YOUNG AND OF AN ADULT FEMALE CHIMPANZEE, SHOWING STRONG SIMILARITY TO THE HUMAN TYPE

Note the inferior, middle, and superior nasal meatus, the frontal and the sphenoid sinus, the ethmoid cells, the position of the sphenopalatine foramen, etc. The prepituitary plane of the braincase is not as much deflected as it is in man. The fossa subarcuata, lying behind and above the internal auditory meatus is much reduced, especially in the adult.

The occlusal relations of the cheek teeth are the same as in man, but the lower canine is more in front of the upper, and the incisors are strongly procumbent.

The anatomy of the nose testifies in the same direction. According to Professor J. Howard McGregor the gorilla nose, although repulsive in human eyes, has in it all the "makings" of a human nose, and acquires chiefly a forward and downward growth of its tip to be trans-

FIG. 301. YOUNG FEMALE GORILLA

Courtesy of the New York Zoological Society. Photographed by Elwin R. Sanborn. Showing the sub-human appearance of the nose, the use of the hand in feeding, the habit of crouching or sitting nearly upright, etc.

formed into a subhuman type. The lowest existing types of human nose (*fig. 302*) indeed retain much of the gorilloid heritage.

The eyes of the great apes could hardly be more human than they are. The fundus of the eye of a chimpanzee, as figured by Johnson (1901), exhibits the most detailed resemblance to that of a negro.

Every close observer of the living animals must have been impressed with their power to focus both eyes at once on a nearby object although, like other simians, they are unable to sustain convergence, except for a brief time.

FIG. 302. A TASMANIAN MAN, SHOWING A VERY LOW TYPE OF FACE, WITH AN EXCESSIVELY WIDE FLAT NOSE

Courtesy of Sir Harry Johnston. Photograph by J. W. Beattie, Hobart, Tasmania

The lacrymal bone of the anthropoids, as described by Le Double (1900) is similar to that of man and even exhibits similar variants.

Since Darwin's classic studies on the expression of the emotions in man and apes, it is well known that in the general arrangement and functions of the mimetic muscles the great apes are very man-like, except in the degree of development of certain muscles which have

become more or less degenerate in man. In the gorilla, according to Duckworth (1915, p. 180), "differentiation of the muscles of expression has reached a stage not far removed from that obtaining in man."

FIG. 303. PHOTOGRAPH OF A CHIMPANZEE FOCUSSING THE EYES ON A NEARBY OBJECT
Courtesy of Professor W. T. Shepard

The ear of the gorilla is essentially of human type. Keith (1906) has made extended statistical records of the frequency of "orang," "chimpanzee" and "gorilla" types of ear in modern Europeans.

The auditory ossicles of the chimpanzee, according to Doran (1875, p. 379) "are, taken as a whole, most like those of *Homo*. *T. gorilla* closely resembles *Homo* in its incus and stapes, but less in its malleus; *Simia* more resembles *Homo* in the head and articular surface of the malleus. . . . . Though the incus of some species of *Hylobates* exhibits a tendency to low type in the malleus, and particularly in the stapes, this genus is quite anthropoid. In their ossicula, but most markedly in the stapes, these apes are much more allies to *Homo* than to the lower monkeys."

The whole morphology of the tympanic cavity and surrounding parts, as set forth by van Kampen (1905) and verified by the writer,

FIG. 304. FRONT PART OF THE SKULL OF A YOUNG CHIMPANZEE, TO SHOW THE SUB-HUMAN CONSTRUCTION OF THE ORBITAL REGION

shows (a) that man is a member of the catarrhine or Old World series, (b) that his nearest relatives are the great apes, especially the gorilla and chimpanzee, and (b) that he has advanced beyond them, especially in the specialization of the tympanic bone into a tympanic plate.

The course of the internal carotid artery and its branches in the auditory region adds further evidence in the same direction (Gregory, 1920).

The fossa subarcuata on the medial encephalic surface of the periotic bone is present and of large size in all the lower primates from the Eocene lemuroids up to and including the gibbon, but it is vestigial in the adult chimpanzee (*fig. 300*) and gorilla, and is variously reduced or vestigial in adult human skulls. It is well developed in infant and

fœtal human skulls, and in the fœtal gorilla skull figured by Deniker (*1885, Pl. xxv, fig. 3*), but is vestigial in an infant gorilla. The delay in its closure in man may be secondary, but it is significant that only in man and the great apes among the primates do we find the marked reduction or virtual loss of this fossa.

In a review of the evolution of the dentition it seems hardly appropriate to digress from the main subject even so far as I have, but the reader will understand that unless the anthropoid apes are the nearest living relatives of man, it is quite useless to attempt to trace the evolution of human dentition along the paths followed in this review. One is tempted to go on and show that the same or similar degrees of resemblance between the great apes and man obtain in many other parts of the organism, particularly in the locomotor skeleton, but I must be content with the assertion, based chiefly on my own observations, that the resemblance holds good in the vertebral column as a whole; in the scapula, coracoid, clavicle, humerus, radius and ulna; in the bones of the manus; in the pelvis, femur, tibia and fibula; and (with certain conspicuous exceptions noted below) in the bones of the foot. As to the locomotor musculature, it is well known that certain variants in man may be regarded as ataval reversions to the conditions preserved in anthropoid apes (Huntington, 1918). With regard to the muscular system of the gorilla, Duckworth (1915, p. 179) says: "The muscles correspond severally with very close accuracy to those of man, and in fact the number of distinctive human muscles, at one time thought to be thirteen, is now reduced to three (M. plantaris, peroneus tertius and serratus posticus inferior). The acromio-trachelian and dorsi-epitrochlear muscles distinguish the gorilla, not being normal in man."

Many of the resemblances referred to in the foregoing pages may have been developed by parallelism or "analogous variation" after the human and chimpanzee-gorilla stems began to diverge from each other, but taken as a whole the testimony of comparative anatomy affords cumulative evidence for Darwin's inference "that some ancient member of the anthropomorphous subgroup gave birth to man." *The detailed studies of the dentition in Part IV of this review leads me to the conclusion that that "ancient member of the anthropomorphous subgroup" was closely allied to or even identical with either Sivapithecus or Dryopithecus (fig. 305) of the Miocene Simiinæ.*

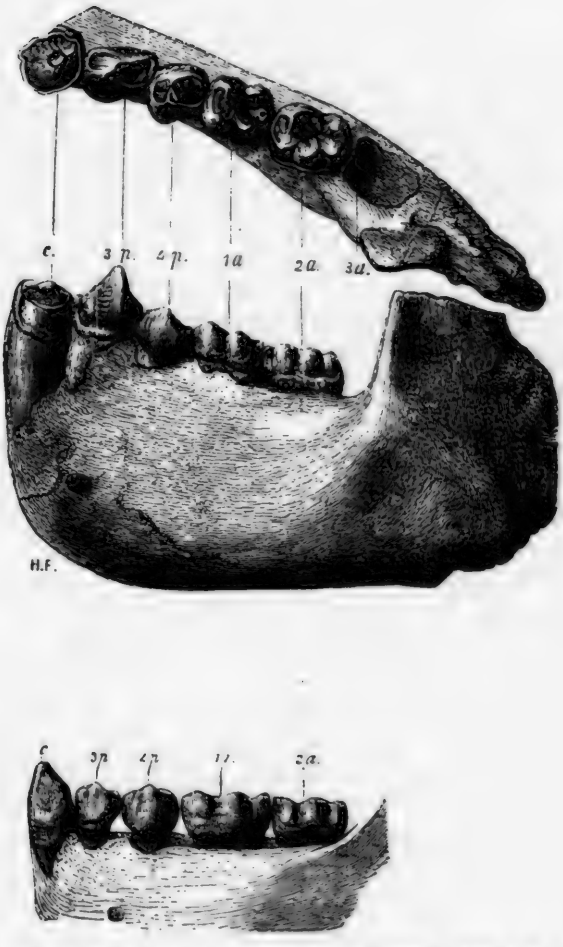


FIG. 305. LOWER JAW OF *Dryopithecus fontani* AND LOWER TEETH OF A TASMANIAN YOUTH, WITH THE LOWER CANINE PROJECTING ABOVE THE LEVEL OF THE CHEEK TEETH. AFTER GAUDRY

EVOLUTION OF THE DENTITION IN CORRELATION OR COADAPTATION WITH THE EVOLUTION OF THE LOCOMOTOR APPARATUS

In the later stages of human ascent the characters of the human dentition have doubtless been influenced by the upright posture assumed by man and his immediate ancestors; even in the earlier stages changes in the locomotor apparatus, connected with a shift from one sort of environment to another, doubtless affected indirectly the jaws and dentition. It may then be advantageous at this point to review the coincident evolution of the locomotor apparatus and of the dentition.

With regard to the earlier stages of the limbs and the posture of the body in the line of human ascent, Klaatsch and Wood-Jones (1918, p. 18) have vigorously insisted that "man and his ancestors were never quadrupeds as the dog or the elephant or the horse." But has any competent authority ever maintained that they were? There never has been any necessity for assuming that the more remote primate ancestors for man were highly specialized for quadrupedal locomotion on the ground. The comparative anatomical and, as is now known, the palæontological evidence (Gregory, 1920) decisively indicates that in Lower Eocene and probably even earlier times the Primates were not like ordinary terrestrial quadrupeds, with extremities adapted for swift running on the ground, but were arboricolous animals, with extremities adapted for leaping and climbing in the trees. As this subject is more fully considered elsewhere (1920, pp. 233–241), the main stages in the evolution of the locomotor apparatus and their general relations with the skull and dentition, from the primitive reptilian to the human stage, may here be reviewed very briefly as follows:

Stage 1. Primitive reptilian stage, represented by lizard-like reptiles of the Carboniferous, Permian and later Ages. Body elongate, dragged or propelled near the ground, limbs held out at elbows and knees, extremities pentadactylate, with spreading digits. Neck short, skull large, more or less like that of a lizard, slightly bent upon vertebral column; face elongate; teeth numerous, simple. Food habits carnivorous or insectivorous. (See Part I, pp. 101–102.)

Stage 2. Advanced mammal-like reptiles (small cynodonts) of the Triassic. Body raised well off the ground in walking, but elbows and knees still everted. Skull opossum-like, with carnivorous-insectivorous dentition. (See Part I, pp. 102–111.)

Stage 3. Primitive *Amphitherium*-like mammals of the Jurassic. Skeleton unknown, but very probably of primitive placental type with pentadactylate extremities, including a more or less divergent first digit in manus and pes. Dentition of primitive insectivorous type. (See Part I, pp. 123–127.)

Stage 4. Primitive lemuroid primates of the lower Eocene. Habits arboricolous, skeleton adapted for leaping, climbing and perching in the trees; extremities quadrumanous, with strongly divergent hallux in pes; skull like that of *Notharctus;* dentition adapted for mixed diet of insects, fruits, eggs, small birds, etc. Dental formula $I\frac{2}{2}C\frac{1}{1}P\frac{4}{4}M\frac{3}{3}$. (See Part II, pp. 238–253.)

Stage 5. Ancestral catarrhine primates of the Lower Oligocene (e.g., *Parapithecus*). Fossil remains of locomotor skeleton not yet discovered, but all their modern descendants have the important power of sitting more or less upright on the ischial tuberosities (*fig. 214*). This habit encourages the use of the hands to assist the lips, tongue and teeth in the manipulation of the food. Cranium carried at moderate angles to vertebral column. Optic and auditory parts of skull probably well developed but not excessively enlarged. Muzzle short; dentition much as in *Parapithecus* with dental formula of $I\frac{2}{2}C\frac{1}{1}P\frac{2}{2}M\frac{3}{3}$. Incisors simple, with cingulum; canines small, not enlarged for offense or defense; premolars more or less bicuspid; molars with low, round cusps; upper molars quadri- lower quinquetubercular. Diet probably mixed: insects, fruits, eggs, etc. (See Part IV.)

Stage 6. Primitive anthropoid apes of the Miocene of India, Egypt and Europe. Again the locomotor skeleton remains to be discovered, the chief parts known being jaws and isolated teeth, but there is strong indirect evidence afforded by the existing anthropoids and by the humerus of *Dryopithecus* that their more primitive Miocene ancestors were already acquiring the enormously important ability to "brachiate," or swing from branch to branch with the body suspended from the upraised arms. Pes probably with grasp-

FIG. 306. YOUNG FEMALE GORILLA

Courtesy of the New York Zoological Society. Photograph by Elwin R. Sanborn. Shows the sub-human form of the foot, which, however, retains the grasping form of the great toe, as in all other known primates but man.

ing hallux.[6] Sitting upright, and erect progression on the ground, both more or less highly developed. Skull sharply deflected on vertebral column. Upper jaw deepened obliquely forward and downward beneath overgrowing frontal portion of skull. Diet mixed: including large fruits with tough rinds, insects, small animals. Central incisors not much enlarged in primitive forms, but becoming very wide in orangs and chimpanzees. Both upper premolars bicuspid; anterior lower premolar with more or less sloping, enlarged antero-external face and compressed tip which shear behind enlarged upper canines. First and second upper molars quadrate with low cusps, becoming wrinkled in orang and to a less extent in chimpanzees. Lower molars with "*Dryopithecus* pattern" of five cusps. (See Part IV, pp. 658–669.)

In the modern anthropoids (*fig. 306*) the head is supported on top of the more or less erect vertebral column, especially in the sitting or squatting posture. Locomotion, even on the ground, is no longer quadrupedal in the primitive way, the gibbon often walking erect and the chimpanzee and gorilla frequently balancing the body from the hips and touching the ground with more or less folded hands. Thus the anthropoids, in acquiring the mode of locomotion called "brachiation," diverged from the primitive catarrhine mode of progression on all fours, and made possible the adoption of fully bipedal habits.

Stage 7. Human stage. ?Pliocene, Pleistocene, Recent. Wood Jones frequently speaks of the "basal mammalian primitiveness" of the human skeleton, without offering any substantial evidence in support of such assertions. He does not recognize the fact that for true "basal mammalian primitiveness" or rather basal placental primitiveness, we must have recourse to studies of the skeleton of the primitive Paleocene and Eocene mammals and of the less specialized unguiculate mammals of the present time. He has also failed to

[6] There is weighty palæontological and comparative anatomical evidence for the view that a strongly divergent, grasping type of hallux was a primitive primate character which has been transmitted, with minor modifications, to all later lemuroids, tarsioids, Platyrhinæ and Catarrhinæ *except man*, who has very probably lost this primitive primate character in adaptation to his upright, bipedal posture and gait. For opposing views on this subject see Gregory (1920, pp. 239–241) and Miller (1920, pp. 229–245).

FIG. 307. SAGITTAL SECTION OF HEADS OF YOUNG GORILLA AND OF MAN. AFTER KLAATSCH

appreciate the fact that the humerus and whole forearm of man are closely related in construction, not to the arm and hand of any of the truly primitive mammals mentioned above, but to the highly specialized "brachiating" type of the chimpanzee and gorilla. Hence it is not necessary, and is indeed directly against the evidence, to push the divergence of man from the other primates back to a point long antecedent to the differentiation of the anthropoid stock; nor is it necessary to ascribe the upright posture of man to direct inheritance from an upright-standing tarsioid, such as *Tarsius; because the cumulative evidence of comparative anatomy shows that man is a specialized offshoot from the anthropoid stem, probably arising after the assumption of upright-sitting, of brachiation, and of more or less erect progression on the ground.*

The erect or semi-erect posture, together with the increasing use of the hands as such and the correlated swelling of the brain, has conditioned or is associated with (*a*) *the forward growth of the cranium and the deflection of the prepituitary plane* (*Keith*), (*b*) *the forward growth of the upper part of the face, and* (*c*) *the reduction in size and retraction of the jaws and dentition beneath the overhanging nose and forehead, which is so characteristic of the higher races of man.*

THE TRANSFORMATION OF GROUND APES INTO MEN, WITH SPECIAL REFERENCE TO THE DENTITION

The lack of extinct races of men in known fossiliferous formations of the later Tertiary has been most frequently ascribed to "the incompleteness of the geological and palæontological record." The "mystery of man's origin" is widely accepted as a palæontological fact and some hope to discover early representatives of the human phylum far back in Lower Oligocene or Eocene deposits of Asia or even of North America. Such was the concept of Cope, who regarded his Lower Eocene "*Anaptomorphus*"[7] as a direct ancestor of man, while Hubrecht, Wood Jones, and Boule[8] have adopted more or less similar views.

[7] Cope: *Tetonius* (*Anaptomorphus*) *homunculus*, Part II.

[8] In his latest work (1920), Boule favors the more conservative view that man is probably an offshoot of the "Old World" stock, which also gave rise to the anthropoids and to the cynomorphous monkeys.

Those who hold such opinions concerning the origin of man must explain all the profound anatomical, physiological and psychological resemblances between existing Simiidæ and Hominidæ as owing to convergence and to homoplastic (parallel) evolution. To the same modes of evolution they must ascribe all the minute and fundamental resemblances between Simiidæ and Hominidæ in respect of the dental characters set forth in Parts IV and V of this review. Finally, they must postulate the existence of a long series of genera and species representing an unknown and very distinct family of primates, ranging from the Lower Eocene onward, but of which (unless "*Anaptomorphus*" be accepted as a direct ancestor of man) no trace has ever been found in any age.

Such assumptions seem reasonable to me only when considered in the abstract and without due realization of the force of the contrary evidence. I, on the contrary, must and do accept the palæontological record much as it stands; I must hold that *as the evidence from taxonomy, palæontology, comparative anatomy, physiology and psychology for a very near relationship of the Simiidæ and Hominidæ is cumulative and decisive, there is no necessity for postulating the existence of Eocene Hominidæ as a family distinct from the Simiidæ. A fair series of structural gradations lies already at hand, leading from the oldest lemuroid primates, through the stem of the tarsioids, to Parapithecus of the Lower Oligocene, and thence through Propliopithecus, Dryopithecus,*[9] *Sivapithecus, Pithecanthropus, or through genera nearly allied to these, to the emergence of the Hominidæ as a distinct family in Pliocene and early Pleistocene times.* Such a series may be deemed too strongly monophyletic at a time when the fact of polyphyletic branching of mammalian groups is sometimes mistakenly assumed to mean that the known phyla run back on parallel lines to infinitely remote "premammalian" stocks. This much I am willing to concede to the "imperfection of the palæontological record:" that possibly one or more of the above-named genera may eventually be shown not to lie in the *direct* line of human ascent, but to be set a little way off to one side by the possession of some distinctive and peculiar special-

[9] The recently discovered species (?) *Dryopithecus mogharensis* (Fourtan, 1920), from the Lower Miocene of Egypt, adds an important item, tending to bridge the gap between the older genus *Propliopithecus* and the later and more advanced genus *Dryopithecus*.

ization. But so far as I am able to judge, the known remains, regrettably imperfect as they are, afford at least a fair structural series illustrating the evolution of the dentition and lower jaw, from *Parapithecus* to the anthropoids and to the Hominidæ.

From this wide contrast in view-point it will follow that, *if I am right, then those who hold the opposing views would fail to recognize a direct ancestor of man of Miocene age even if it were represented by a complete skeleton,* since they would expect to find it abounding in the diagnostic characters of recent Hominidæ and to be widely different from the contemporary Simiidæ. *Again, if my conclusions are correct, the precursors of man should be found in rocks of Pliocene age and should be large ground apes closely allied to or identical with Pithecanthropus; while if the others are right, the "real Eoanthropus" should be sought in the Lower Eocene and should be a large-brained primate of small size, perhaps more or less transitional between the Eocene tarsiods and the Hominidæ.*

In fairness to those who hold different views from mine of the origin of the Hominidæ, I must emphasize the fully human character of the Heidelberg dentition (see p. 125 below) and the lack of transitional stages of Pliocene age.

No matter what view we take as to the origin of man from other primates: where were the Pliocene Hominidæ and what were they like? Extensive mammalian faunas of Pliocene age have been described from various places in Asia, Europe and North America, but the Hominidæ are so far conspicuously absent from the records. Although such negative palæontological evidence is by no means decisive, it would seem likely that if the Hominidæ had been both widely distributed and plains-living mammals during the Miocene and Pliocene, some hint of their remains would have been found in some part of the globe along with those of the numerous known plains-faunas of late Tertiary age. *Such as it is, the negative palæontological evidence seems in harmony with the hypothesis that, during the late Tertiary, the Hominidæ had not yet extensively invaded the plains, and that in some restricted and more or less isolated Palæarctic region they were in course of differentiation from ground-living apes inhabiting the border regions between forests and plains.*

If the femur of Pithecanthropus be associated with the skull, as held by nearly all authorities, then we have definite proof that early Hominidæ or progressive Simiidæ of late Pliocene or early Pleistocene age already walked erect upon the ground. There is some evidence for the view of Pocock (1920) that even the earlier anthropoids were already adapted for erect progression on the ground, and that the modern orang and gibbon have become secondarily specialized for arboreal life.

The thoroughly terrestrial rather than semi-arboreal characters of the skeleton of the Pleistocene neanderthaloids and of all later races of men, show that the erect gait was assumed at a relatively early date. It is, as noted above, extremely probable that many of the diagnostic characters of the human dentition were more or less connected with the complex series of readjustments that took place when the skull became balanced on top of an erect backbone, and when the hands, set free entirely from the locomotive functions, became increasingly skillful in assisting the teeth in the killing, preparation and manipulation of food.

Such a radical transformation of the jaw and dentition from a *Dryopithecus*-like type was correlated, apparently, with a pronounced change in food habits, from a prevailingly frugivorous to an omnivorous-carnivorous stage, and was even more intimately dependent upon a still greater transformation in the brain and braincase, from a primitive anthropoid to a human condition, which brought with it revolutionary disturbances and readjustments of the digestive apparatus and of the ductless-gland complex that controls the growth and proportions of skeletal parts.

It may well be that this transformation was more complete and far reaching in the Hominidæ than any which had taken place in other mammals during the same period. But in this connection we must bear in mind in the first place the vast extent of a single geological epoch, all recent work indicating that the older estimates were far too low, so that the time from the Middle Miocene to the Lower Pleistocene, during which, according to my view, the transformation in question took place, may represent more than a million years—long enough perhaps for the brain to expand from an anthropoid to a low human stage and for the accomplishment of all the correlated changes, including those in the dentition. And in the second place

FIG. 308. SERIES OF SKULLS OF OLD WORLD PRIMATES. AFTER HAECKEL

Seen from below, showing the relation between the length of the head and the form of the mandible. The forms figured are: (1) gibbon, (2) young chimpanzee, (3) baboon, (4) dolichocephalic Australian (*Homo sapiens australianus*) and (5) brachycephalic German (*Homo sapiens alpinus*).

there are other groups of mammals for which we have evidence of very extensive and revolutionary changes in structure during the second half of the Tertiary period. During this time the tree-sloths evolved out of ground-sloths (Matthew), the whalebone whales lost their teeth and substituted baleen plates (Abel), and the ancestors of the sperm whale acquired very extraordinary specializations of the whole skull (Abel).

FIG. 309. WELL PRESERVED HUMAN DENTURE, SHOWING NORMAL OCCLUSION
Courtesy of Dr. Bernhard W. Weinberger

In contrast to such radical and profound changes in function, and in the direction of evolution, are the many well-known cases involving rather an intensification of given functions and further progress in the same direction as in earlier stages. Such has often been the case in animals that have remained in the same environmental zone, as have the plains-living ungulates, and have simply improved their

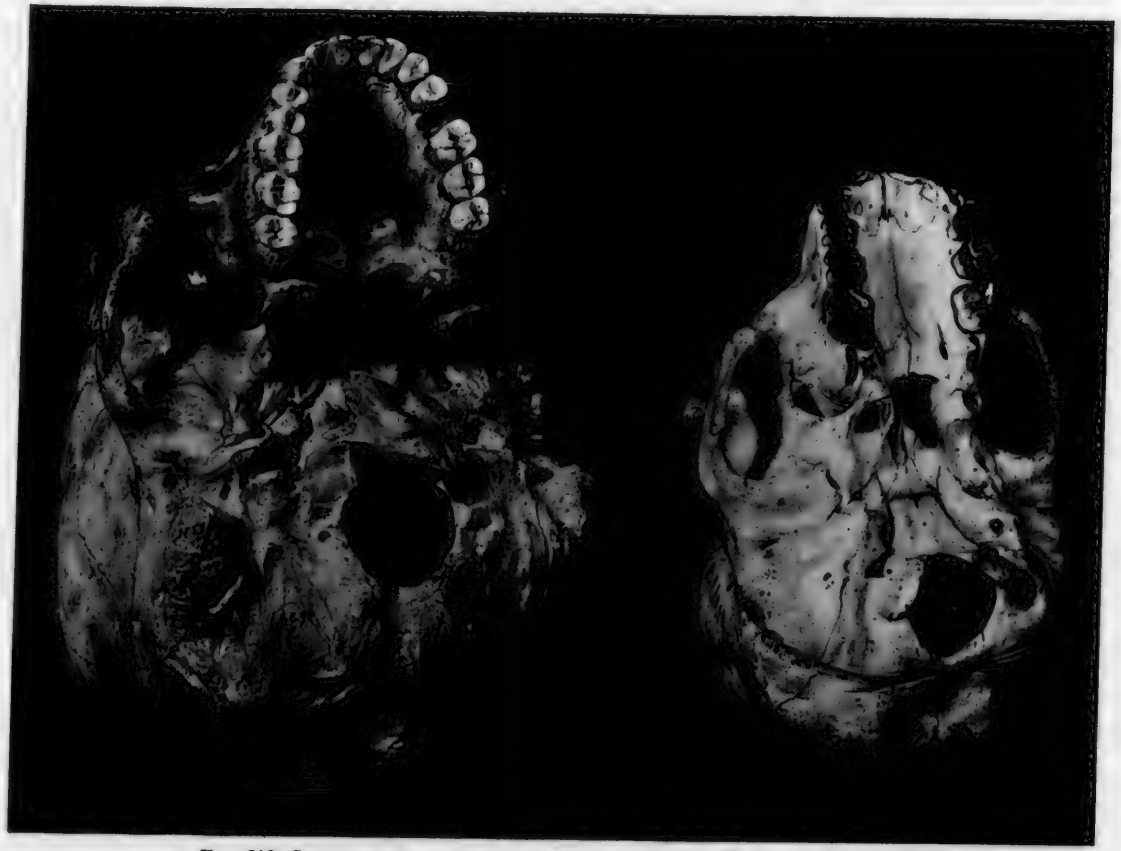


FIG. 310. SKULLS OF AUSTRALIAN NATIVE (FEMALE) AND OF YOUNG GORILLA

Oblique view of under side, showing marked divergence in habitus (enlarged teeth of gorilla, enlarged braincase and reduced teeth of man) associated with fundamental unity of heritage.

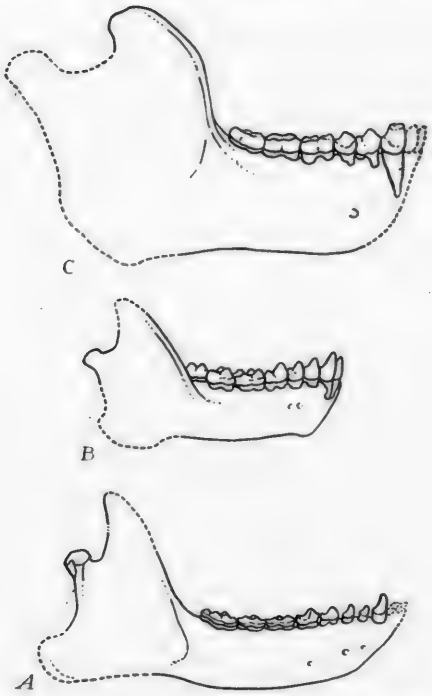


FIG. 311–312, INCLUSIVE. EVOLUTION OF THE HUMAN MANDIBLE. SIDE VIEW

Fig. 311. First stage: Eocene lemuroid, represented by *Notharctus osborni*, Middle Eocene, Wyoming. Dental formula: $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{4}{4}\ M\frac{3}{3}$. Jaw elongate, with primitive form of angle (A).

Second stage: represented by *Parapithecus fraasi*, Lower Oligocene, Fayûm, Egypt. Dental formula: $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{2}{2}\ M\frac{3}{3}$. Jaw shortened, angle beginning to expand (B).

Third stage: represented by *Propliopithecus haeckeli*, Lower Oligocene, Fayûm, Egypt. Dental formula: $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{2}{2}\ M\frac{3}{3}$. Jaw much shortened and deepened, angle expanded (C).

Fig. 312. Fourth stage: represented by *Dryopithecus* (A) and *Sivapithecus* (B), Miocene of Europe and India, respectively. Dental formula: $I\frac{2}{2}\ C\frac{1}{1}\ P\frac{2}{2}\ M\frac{3}{3}$. Jaw much deepened, incisors slightly procumbent.

Fifth stage: lowest human type, represented by jaw of *Homo heidelbergensis*, Pleistocene, Germany. Dental formula as before. Jaw very massive, without protruding chin. Incisors erect, canine reduced to level of other teeth (C).

Sixth stage: low human type, represented by the jaw of an Australian native (*Homo sapiens australianus*). A bony chin developed, ascending ramus narrower (D).

Seventh stage: modern man. Bony chin protruding, ascending ramus weak (E).

mode of locomotion and dental apparatus without radically altering the plan of them. These cases being numerous and well-known are apt to be taken as the standard examples of the way that evolution normally proceeds, and from thence may arise the unconscious impres-

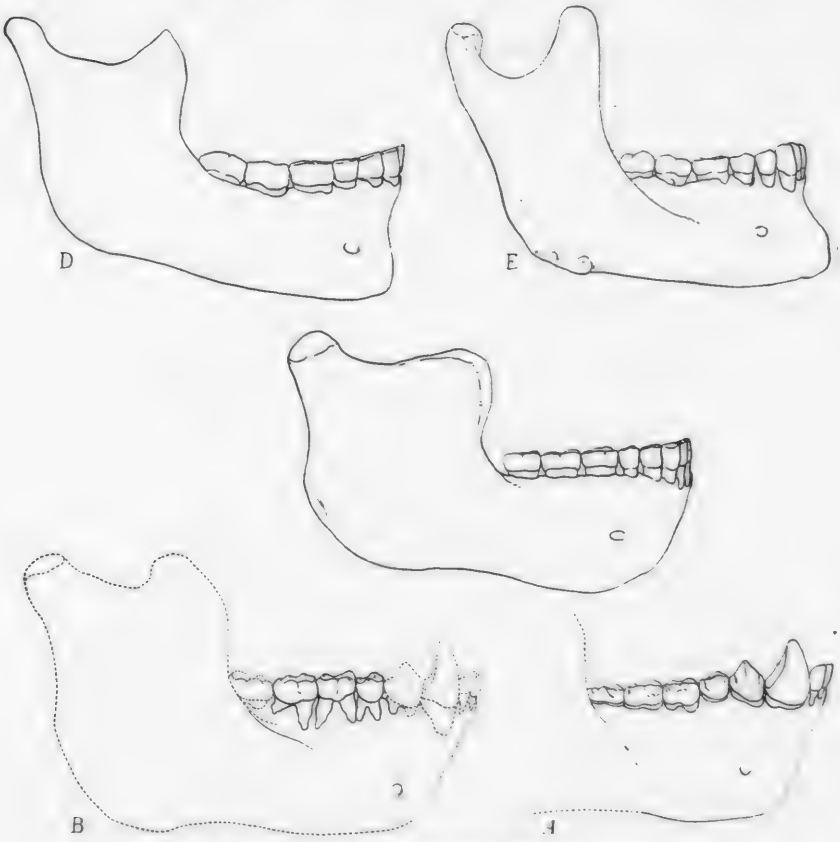


FIG. 312. EVOLUTION OF THE HUMAN MANDIBLE (CONTINUED)

sion that nature is limited to that kind of "orthogenetic" evolution. *But all the great evolutionary advances, as when tetrapods evolved from fishes, or when mammals evolved from reptiles, have been revolutionary in character, since they involved profound changes and readaptations in the methods of locomotion and of feeding.*

The supposed transformation in skull and dental characters by which the human stage was finally attained, is thus described in my "Studies on the Evolution of the Primates" (1916, pp. 277–280):

"The anthropoids are chiefly frugivorous and typically arboreal; when upon the ground they run poorly and (except in the case of the gibbons) use the fore limbs in progressing. Thus they are confined to forested regions. Man, on the other hand, is omnivorous, entirely terrestrial, erect, bipedal and cursorial, an inhabitant primarily of open country.

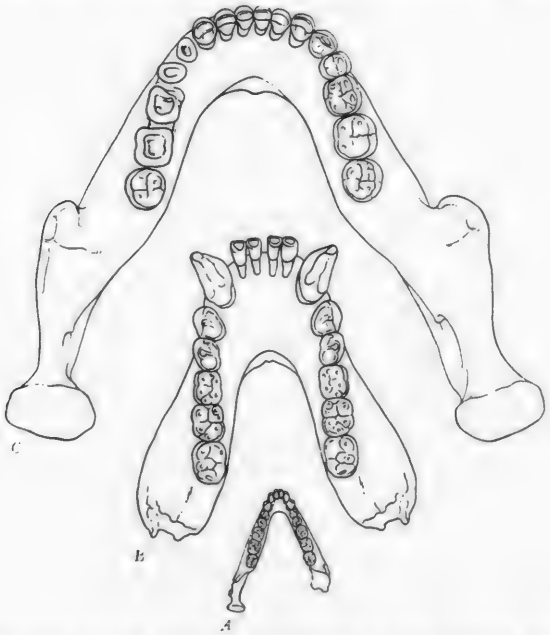


FIG. 313. EVOLUTION OF THE HUMAN MANDIBLE AND LOWER DENTAL ARCH. VIEWED FROM ABOVE

First or super-tarsioid stage: represented by *Parapithecus*. Opposite halves of mandible converging (A).

Second or *Dryopithecus* stage: *Dryopithecus fontani*, composite restoration, based mostly on the figure given by Smith Woodward (1914); front teeth supplied from Gaudry. Intercondylar diameter increased, dental arch Π-shaped, tooth rows parallel, canine enlarged (B).

Third or primitive human stage: *Homo heidelbergensis*. Intercondylar diameter excessively increased, dental arch Ω-shaped, canine reduced (C).

The anthropoids use their powerful canine tusks and more or less procumbent incisors for tearing open the tough rinds of large fruits and for fighting. Primitive man, on the contrary, uses his small canines and more erect incisors partly for tearing off the flesh of animals which he has killed in the chase with weapons made and thrown or wielded by human hands.

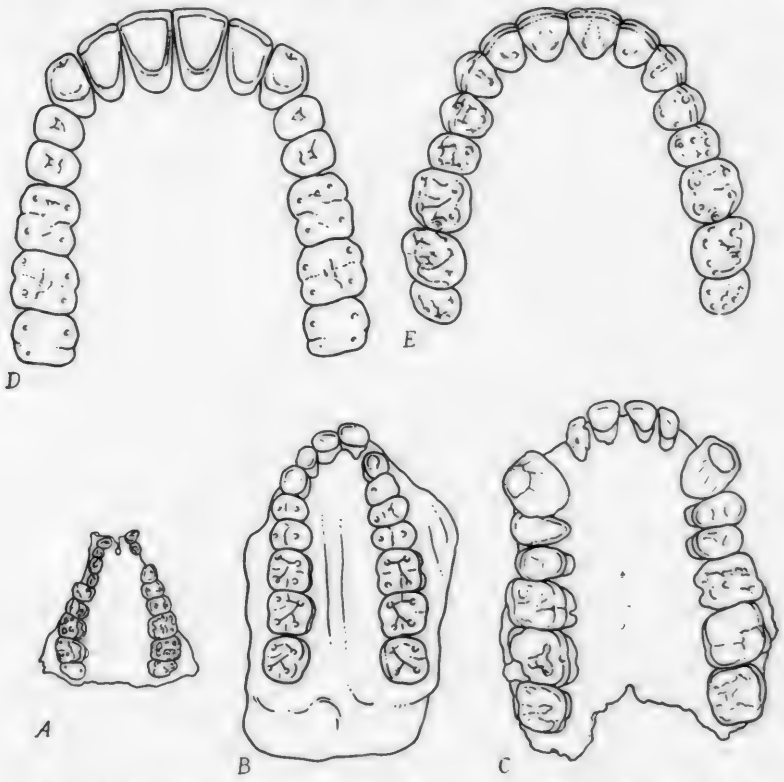


FIG. 314. STRUCTURAL SERIES SHOWING EVOLUTION OF HUMAN PALATAL ARCH

First stage: represented by *Necrolemur*, with convergent or Λ-shaped palatal arch (A).

Second stage: represented by *Oreopithecus*. After Schwalbe. (Palate crushed laterally) (B).

Third stage: represented by *Palæopithecus*, with enlarged canines and straight tooth rows (C).

Fourth stage: represented by "Mousterian youth," with small canines and rounded palatal arch (E).

Fifth stage: represented by Tasmanian (after Keith), with Π-shaped arch (D).

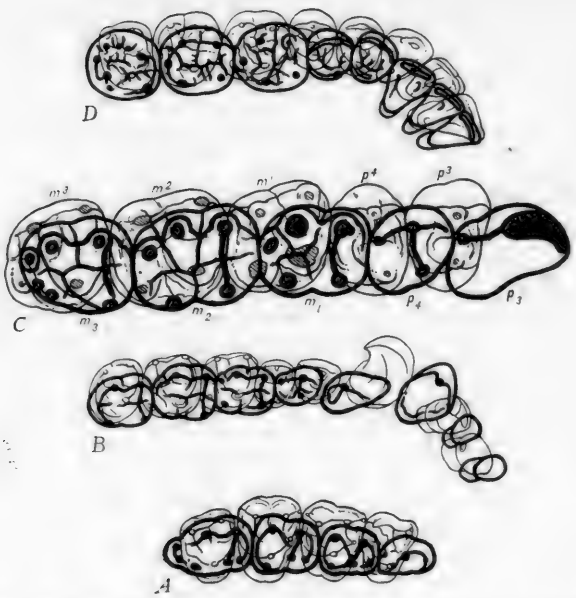


FIG. 315. EVOLUTION OF OCCLUSION. EOCENE LEMUROIDS TO MAN

A.—Eocene lemuroid *Pelycodus*. B.—Modern gibbon *Hylobates*. C.—Modern gorilla. D.—Modern man.

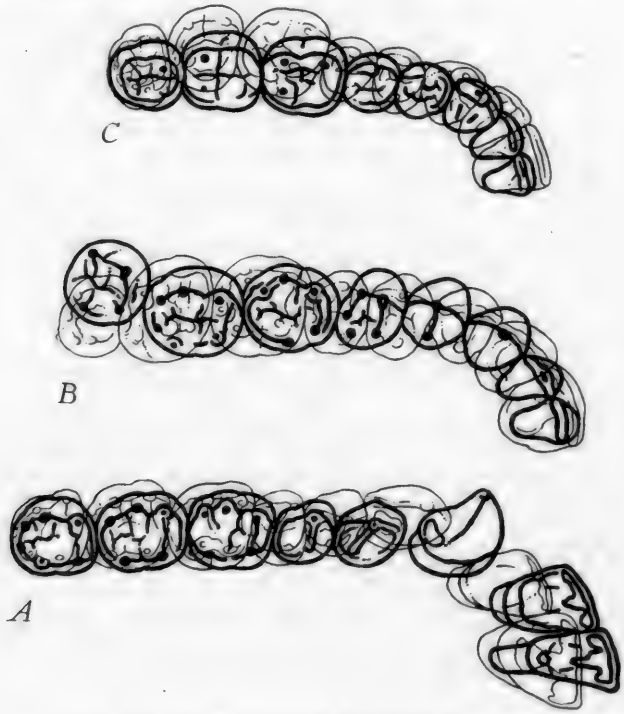


FIG. 315 *bis*. EVOLUTION OF OCCLUSION (CONTINUED)

A.—Chimpanzee. B.—Mousterian youth. C.—Modern man

These implements and weapons also usually make it unnecessary for man to use his teeth in fighting and functionally they compensate for the reduced and more or less defective development of his dentition.

"The comparative anatomical evidence alone is, I believe, sufficient to establish that, in spite of these wide differences in habitus, man is closely akin to the chimpanzee-gorilla group. All competent authorities will agree with MM. Boule and Anthony and Professor Keith that man bears an indelible stamp of remote arboreal ancestry, that upright or semi-upright progression in the trees was a prelude to the profound changes

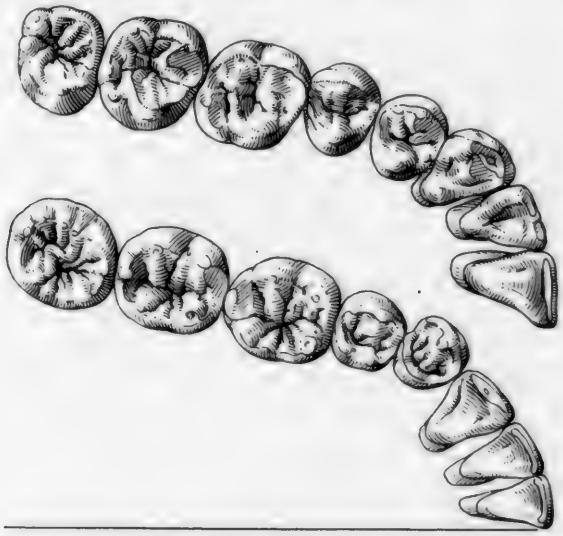


FIG. 316. RIGHT UPPER AND LEFT LOWER HUMAN TEETH

Specimen loaned by Dr. Bernhard W. Weinberger. (Cf. *fig.* 315 bis, C)

initiated by the assumption of bipedal progression upon the ground. The change from arboreal to terrestrial life must have been correlated with a great change in food habits from a chiefly frugivorous to an omnivorous diet. In all known anthropoids, both recent and extinct, the powerful jaws and teeth seem to be adapted for tearing open the tough rinds of larger fruits, while early man, on the other hand, was a great hunter and flesh eater, like most primitive tribes of the present day. And every observer knows what efficient structures the incisors and canines of savages are in tearing off pieces of flesh.

FIG. 317. EXHIBIT ILLUSTRATING THE ANCESTRY AND RELATIONSHIPS OF MAN, IN THE AMERICAN MUSEUM OF NATURAL HISTORY

1.—Gibbon (*Hylobates*); 2.—Orang; 3.—Gorilla, female; 4.—Gorilla, male; 5.—Gorilla, young; 6.—Reconstruction of *Pithecanthropus* skull, and bust of same, by Prof. J. H. McGregor; 6.—Cast of skull top of *Pithecanthropus*; 7.—Reconstruction of *Pithecanthropus* skull, by J. H. McGregor; 8.—Cast of skull of the "old man of La Chapelle aux Saints" (Neanderthal race); 9.—Cast of Talgai skull (primitive Australian race); 10.—Cast of skull of old Crô-Magnon man; 11.—Skull of modern man (?Mediterranean race).

The black lines indicate genealogical relations, so far as inferred by the writer. The small objects represent casts of teeth and jaw fragments of extinct anthropoids and men, as described in Parts IV. V. The one at the bottom of the phylogenetic tree represents *Propliopithecus*.

"Hence *all the non-anthropoid and distinctively human features in the dentition of man seem to be relatively late specializations, which constitute a functionally correlated series.* This complexly interrelated series of more or less simultaneous changes included the following elements:

(1) Shortening of the muzzle and symphysis.

(2) Retraction of all the anterior teeth, the incisors becoming more erect, the canines decreasing in size, and the 'edge-to-edge bite' becoming further emphasized.

(3) Reduction in size of the front lower premolar and the completion of its bicuspid character.

(5) Increasing convergence of the opposite tooth rows and widening of the intercondylar diameter of the mandible (*figs. 300, 308*).

(6) Rounding of the molar crowns (*fig. 283*), progressive obliteration of the *Dryopithecus* pattern of the molars (*fig. 286*) and in some cases progressive loss of the hypoconulid on the second and third lower molars. Progressive reduction of the third upper molar from a more quadrilateral to a more tritubercular pattern.

(7) A change in the predominant movement of the mandible from a more ruminant-like, obliquely transverse movement, to movements in all directions and of a partly rotary character. (Especially correlated with the reduction of the canines.)

(8) A long and complexly interrelated series of changes connected with the assumption of the upright posture, the enormous increase in the braincase and consequent balancing of the head upon the neck. This influenced the dentition, especially by changing the insertion areas of the jaw muscles (*cf.* Miller, 1915) and perhaps permitted retrogressive changes, due to the diminished functional importance of teeth as compared with brains.

(9) A final shifting and readjustment of the whole lower dental arch in such a manner that the upper incisors finally overhung the lower incisors, and that each lower molar, which formerly articulated with two upper molars, comes to articulate [on the outer side] chiefly with only one upper molar.[10]

"In brief, the skull and dentition of more advanced types of man in comparison with those of all anthropoids exhibit the following adaptive characters:

[10] Although this "end-to-end" articulation of upper and lower molars is regarded by orthodontists as abnormal, yet it represents a structural stage beyond the normal and further away from the primitive anthropoid condition; and as it occurs in a considerable percentage of well-preserved modern dentures, it may become more frequent in the future.

enormous expansion and deepening of the braincase; extreme shortening of the face;

retraction of the front part of the lower dental arch;

reduction in size of the dentition;

upper and lower tooth rows forming a more or less rounded arch; canines not protruding much above the level of the other teeth; anterior lower premolars transversely widened and fully bicuspid;

fusion of the premaxillaries with the maxillaries;

lower jaw with progressively protruding chin, early losing the inferior symphyseal ledge;

reduction of the supraorbital crest (tori supraorbitales);

extreme retraction of jaws beneath braincase;

articular eminence for the lower jaw small and strongly convex . . .;

glenoid fossa becoming deep;

zygomatic arch feeble;

mastoid processes large and prominent;

tympanic plate (which is elongate and spout-like in the lower anthropoids) abbreviated;

carotid canal (which pierces the petrosal) much enlarged. . . . . (*fig. 310*)."

II. THE DENTITION OF EXTINCT AND OF RECENT HOMINIDÆ

In the succeeding pages I shall review further evidence tending to show that the jaws and dentition of the extinct Hominidæ, especially those of the Heidelberg man and of the Mousterian youth, retained numerous characters reminiscent of the *Dryopithecus* group of the Simiidæ; that many of their diagnostic human characters may fairly be interpreted as quantitative, or allometric, changes from the *Dryopithecus* type, while others, such as the substitution of the +-shaped for the "*Drypopithecus*" pattern of the lower molars, arise through a mingling of "allometric" and "rectigradational," or qualitatively new, changes; also that distinct traces of the evolution of the older or simian condition into the newer or human stage are observable.

PITHECANTHROPUS ERECTUS

In Part IV it was noted that the exact geological age of *Pithecanthropus erectus* has been long disputed, its discoverer, Dubois, assign-

ing it to the Pliocene, but later investigators regarding it as of early or mid-Pleistocene age. It was associated with a varied fauna of mammals closely related to those of the Indian Siwaliks, of Pliocene age (Osborn, 1915, p. 76) and it thus affords another item of evidence in favor of the widely accepted opinion that man originated in central Asia. The precise zoölogical status of *Pithecanthropus* is also still unsettled; and at present it is largely a matter of definitions and of individual viewpoint whether we regard it as a very progressive but aberrant ape, a very primitive man, or a true "missing link." In any event its value is not lessened, as indicating the close relationship of the Simiidæ and the Hominidæ.

If the Hominidæ, as I believe probable, have been derived, in Miocene times, from that section of the *Dryopithecus-Sivapithecus* stock which gave rise to the gorilla-chimpanzee group, then the Pliocene Hominidæ or "precursors" must have had canine teeth and dental arches which were in a transitional stage between that of the Miocene *Dryopithecus* and the definitive human stage attained in Pleistocene and later men. Such transitional conditions have been assigned to *Pithecanthropus*, in the reconstructions of its skull and dentition by Dubois, McGregor and others, and would seem to be warranted by the more ape-like form of its calvarium and temporal muscle-area and by the extremely large size and low characters of its upper molar teeth. But the palæontological proof is not yet at hand.

The two upper molar teeth assigned to this genus have been described in Part IV, fig. 269. The pattern of m^3, it was observed, may perhaps have been derived from that of the corresponding tooth of *Dryopithecus punjabicus*. The internal and external roots are large and very widely divergent. The second upper molar, if correctly identified as such, has the posterior external cusp reduced perhaps even to a greater degree than it is in later races.

HOMO HEIDELBERGENSIS

This famous lower jaw (*fig. 318*), which was described by Schoetensack in 1908, was found embedded in undisturbed sand, in a quarry at Mauer, near Heidelberg, Germany, at a depth of more than 76 feet below the surface. Schoetensack took every precaution to secure and record the most irrefutable evidence of the genuineness

and geological antiquity of the specimen, which was found in a stratum containing the fossil bones of several extinct Pleistocene mammals, including the ancient elephant (*Elephas antiquus*), the lion and the Mosbach horse. These animals, together with the Heidelberg jaw, are regarded by Osborn (1915, pp. 95, 96), as belonging to the Second Interglacial Stage of the mid-Pleistocene, but Schoetensack, Geikie and other authors assign them to the First Interglacial Stage of the Lower Pleistocene. If of Lower Pleistocene age, the Heidelberg jaw shows that the most important diagnostic characters of the dentition of the Hominidæ had already been acquired at the beginning of the Pleistocene epoch and indicates that prehuman transitional conditions must be sought in earlier geological ages. If, on the other hand, the Heidelberg jaw dates only from the Middle Pleistocene, then transitional conditions may be looked for as late as the Lower Pleistocene or Upper Pliocene. In any event, if, as I deem probable, the Hominidæ began to diverge rapidly from the *Dryopithecus*-group in the Middle or Upper Miocene, then transitional stages may be sought from the Upper Miocene through the Upper and Lower Pliocene into the Lower Pleistocene.

As to the detailed characters of the Heidelberg jaw and dentition, it is evident that, as compared with those of all known earlier primates, it has assumed a new and distinctly human habitus. The lower dental arch is short, wide, and evenly round in front, the teeth disposed in continuous series without diastemata, the crowns of all the incisors and canines forming an even series; the canines small and not protruding above the level of the other teeth, the lower canines somewhat suggesting incisors in form; the incisors with nearly vertical rather than procumbent crowns; premolars small, the anterior premolars without the "sectorial" form of the antero-external face; the lower molars wide and rounded, with five main cusps and flat-topped crowns, the pattern being of primitive human type; the whole tooth row apparently adapted for a rotary, grinding motion of the jaw; molar taurodontism, or vertical deepening of the pulp cavity at the expense of the roots, much more pronounced than in modern jaws, but much less so than in Krapina neanderthaloids.

The jaw itself recalls the anthropoid type in the strongly receding chin, in the extreme stoutness of the corpus mandibulæ, in the great

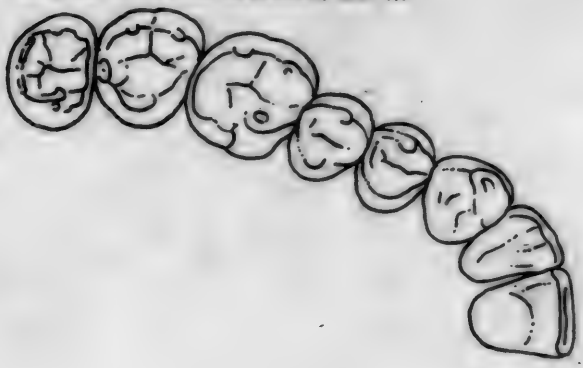
width of the ascending ramus, and of the diameter across the condyles, in the shallowness of the sigmoid notch, and in the restricted space in front for the tongue; but it is essentially human in the shortness of the bony shelf below the "genial tubercles," in the placing of the bony attachment points of the digastric, geniohyoid and geniohyoglossus muscles (A. S. Woodward, 1900) and in the marked divergence of the opposite rami. All of these and other characters collectively indicate that the Heidelberg race was more primitive than and probably ancestral to, the Neanderthal race; and Professor McGregor, after extremely thorough consideration of the subject, has reconstructed the palate and skull along pre-Neanderthaloid lines, giving the skull a quite low forehead, prominent supraorbital tori, an elongate form and rounded upper dental arch.

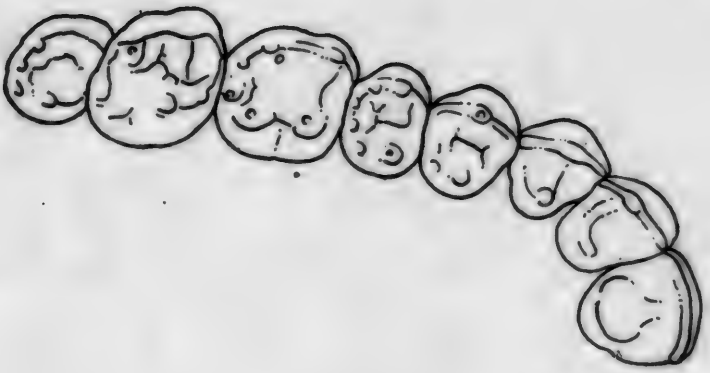
Beneath the primitive human habitus of the dentition some remains of an older simian heritage are still preserved. Thus, as shown in *fig. 265*, the premolars have the patterns fundamentally identical with those of *Sivapithecus*, the most conspicuous difference being the more symmetrical form of the anterior premolar, the anterior external face of which is non-sectorial, in correlation with the reduced size of the upper canines. But the resemblance is much closer to *Sivapithecus* than to the much older *Propliopithecus* in the premolars and in the molars, and this is one reason (although not the principal one) why the relationship seems nearer to the later than to the earlier anthropoid. The *Dryopithecus* pattern is still fairly well preserved in the first molar, which is always the most conservative of the series, but in the second molar the enlargement and widening of the two main cusps of the posterior moiety, namely, the hypo- and entoconids, and the reduction of the hypoconulid, has brought the furrow that separates the meta- and the entoconid, into transverse alignment with the one between the proto- and the hypoconid, while the median longitudinal furrow is becoming straighter, less meandering in its course, so that the human +-shaped pattern is nearly complete. In the third molar the crown is becoming short and rounded, as in man, but although the evidence is not entirely clear it seems probable that a reduced sixth cusp, homologous with that of the *Dryopithecus punjabicus* group, was in process of fusing with the hypoconulid.

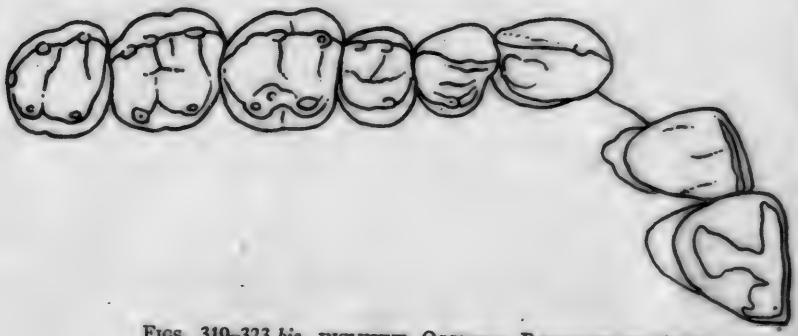
FIG. 318. MANDIBLE OF *Homo heidelbergensis*. AFTER SCHOETENSACK. ONE-HALF NATURAL SIZE

PLATES 14–15

(GREGORY: EVOLUTION OF THE HUMAN DENTITION)







FIGS. 319–323 *bis*, INCLUSIVE. OCCLUSAL RELATIONS OF UPPER AND LOWER

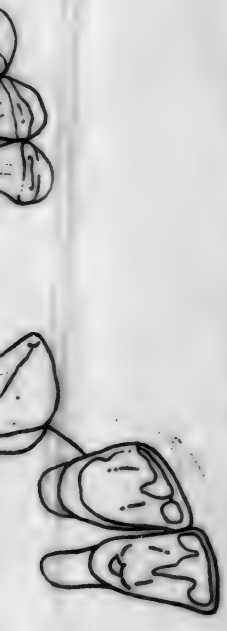
Compare directly with

NS OF UPPER AND LOWER TEETH OF FEMALE CHIMPANZEE, MOUSTERIAN YOUTH, BEDOUIN FEMALE

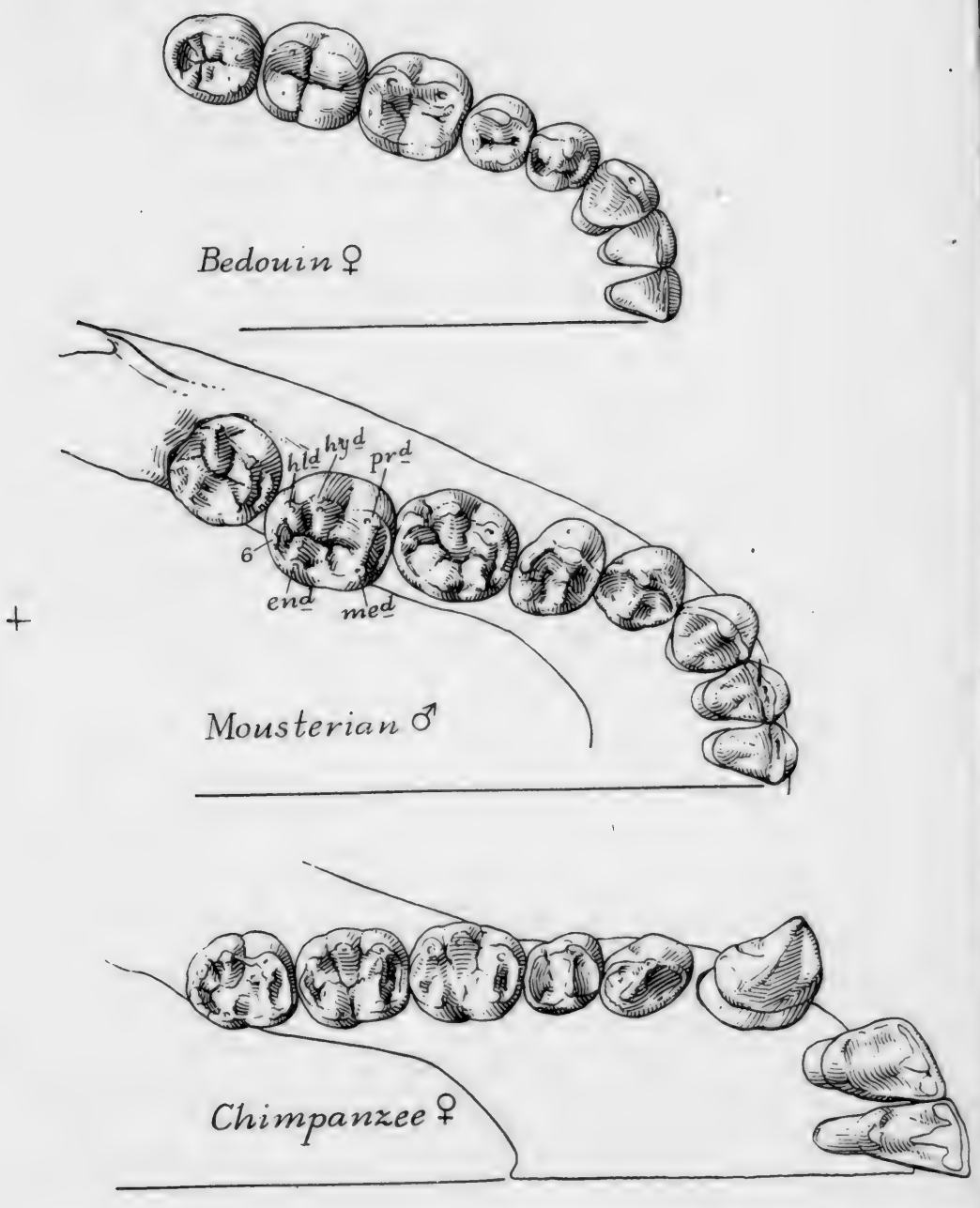
Compare directly with the figures in *plate 15*

(Gregory: E

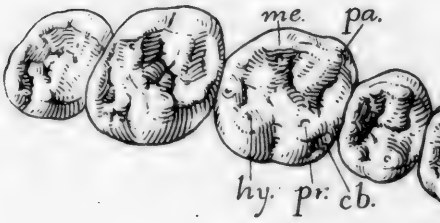
PLATE 14

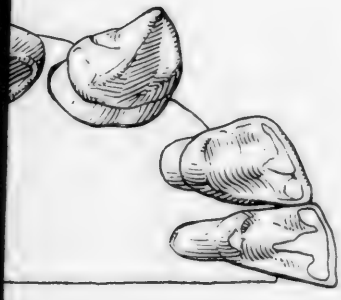


olution of the Human Dentition)

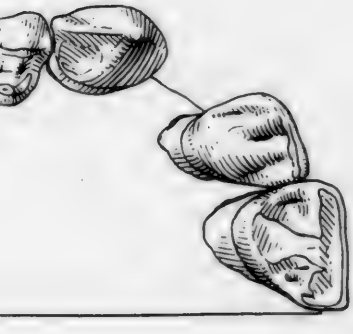


FIGS. 324–329, INCLUSIVE. UPPER AND LOWER TEETH OF FEMALE C





Upper and Lower Teeth of Female Chimpanzee, Mousterian Youth, Bedouin Female



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The phyletic relationship of *Homo heidelbergensis* is discussed in my "Studies on the Evolution of the Primates" (1916, pp. 322–323) as follows:

". . . . The dentition of *Homo heidelbergensis* differs from that of *H. sapiens* only in retaining certain primitive characters which are frequently lost in the higher types. The mandible itself also differs from the higher type solely in its greater size and numerous more primitive characters.

"Hence I recognize no character in this species which would definitely exclude it from ancestry to *H. sapiens* and as it differs from the later type and also from *H. neanderthalensis* only in its more primitive characters and far greater geological age I see no reason for regarding it as an aberrant side line.

"The gigantic size of *H. heidelbergensis* might be cited as a specialization that would exclude this species from the direct line leading to *H. sapiens*, on the ground that in many other phyla of mammals the gigantic members are supposed not to be ancestral to the smaller existing races. But, however it may have been in other phyla, a large stature, or more precisely a massive head and thorax, may well be expected in the ancestral Hominidæ. When the ape-men definitely abandoned the forests and intruded themselves into the gigantic and well-armed fauna of the plains, we may be sure there was no place for undersized gibbon-like beings of pacific habits, but all the conditions at first favored the evolution of powerful and aggressive hunters and fighters, killing with the crudest weapons and tearing off the raw meat with their powerful jaws. As the jaw of the Heidelberg man is lower in type than that of the Neanderthals, it seems likely that his intelligence was also of a lower order, the face extremely heavy, and the forehead retreating, a conception well worked out in Professor Rutot's restoration. . . . . Finally, as the teeth are at least generically identical with those of *H. sapiens*, I see no good evidence either for regarding the Heidelberg race as a distinct genus or for pushing far back into the Lower Pliocene the supposed point of divergence between the lines leading to *H. heidelbergensis* and *H. sapiens*, as in Professor Keith's diagram (1915, p. 501)."

HOMO NEANDERTHALENSIS

Toward the end of the Third Interglacial Period of the Pleistocene or, as some hold, during the Second Interglacial Period, remains of the Neanderthal race were left in various cave deposits in central

Europe. A long line of investigators have contributed to our knowledge of the skeletal anatomy of these extraordinary beings, perhaps the most complete memoir being Boule's description of the old man of Chapelle-aux-Saints.

Although the Neanderthaloids had reached the human grade of organization in most parts of the skeleton, they retained some important characters reminiscent of an early semi-erect heritage. The massive head, instead of being fully balanced on top of the column, was supported by a short, heavy, forwardly-sloping neck, the bones of which recall those of a chimpanzee in having elongate neural spines. In association with the posture of the head and the relatively feeble development of the fore-part of the brain, the prepituitary plane of the skull was much less bent downward than it is in modern human skulls.

As shown by Keith (1914), the combination of a lesser deflection of the forepart of the brain-floor with a forwardly-sloping neck affords room for the massive, deep lower jaw; which could not be accommodated beneath an erectly placed head with sharply deflected prepituitary plane. The depth of the lower jaw, the strength of the ascending ramus, the depth of the alveolar process, and the great development of the supraorbital tori, are possibly all more or less closely correlated with a peculiar specialization of the teeth known as taurodontism and with the powerful grinding action of the lower jaw, which in old individuals causes all the lower teeth to be worn down nearly to the same plane. The lower molars (and probably the upper molars) show a progressive deepening of the pulp cavity and concomitant shortening of the roots, as we pass backward from m_1 to m_3, so that in extreme cases the molar becomes almost as hypsodont as it is in some ruminants (whence the name "taurodont").

The taurodont condition of the cheek teeth has been cited by Adloff (1908) and accepted by Keith (1913) as a specialization (possibly for triturating tough vegetable food [Keith]) which definitely excludes the Neanderthaloids from direct ancestry to any of the later human races. Keith at first supposed that the taurodont characters had been lost in later races, but afterwards he fully accepted Adloff's conclusion. To those who, like the writer, believe that degeneration or loss of characters, has played a large part in human

evolution, the loss or reduction of taurodontism is easily conceivable. But as the molars of the Galley Hill jaw (a specimen which may be older than any of the Neanderthaloids) show only a slight degree of taurodontism, it is possible that Adloff and Keith may be right, and that the extreme Pleistocene Neanderthaloid specialization may bear somewhat the same relation to the modern specialization as the excessive increase in number and fineness of plates in the molars of the Pleistocene mammoth bear to the more primitive condition which has been retained by the modern Indian elephant.

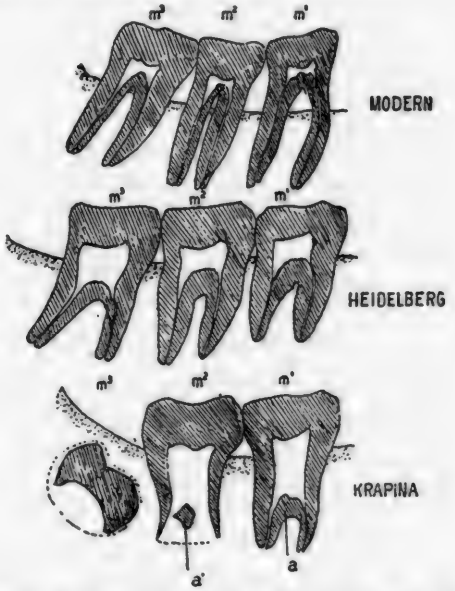

FIG. 330. DRAWINGS FROM SKIAGRAMS OF RIGHT LOWER MOLARS. AFTER KEITH

(1) Modern European, (2) Heidelberg mandible, (3) a Krapina mandible; a, a^1, inner root septum. (1) and (2) after Schoetensack; (3) after Kramberger. Natural size.

Perhaps in correlation with the rotary action of the mandible and with the edge-to-edge bite of the incisors, the articular eminence of fully adult Neanderthaloid skulls is much less pronounced than it is in most modern races, and the glenoid fossa much shallower. The form and relations of these parts and of the tympanic plate and mastoid process are indeed to some extent reminiscent of conditions in the anthropoids (Boule, Keith).

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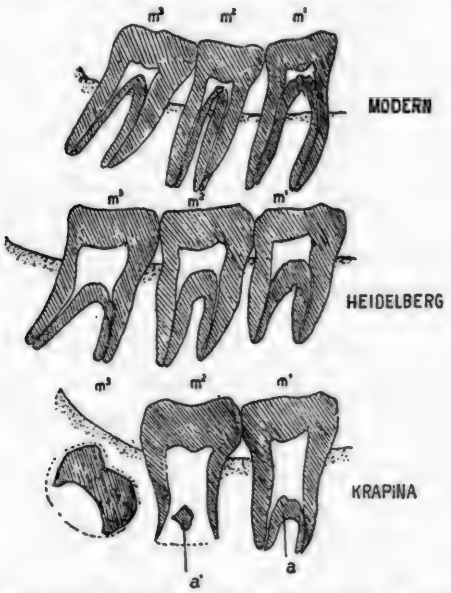

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Dentition of the "Mousterian youth"

The skull and dentition of the "Mousterian youth" are represented by an excellent cast, showing many of the finer details of the dentition, in the J. Leon Williams Collection of the American Museum of Natural History. I also had for comparison some photographs of the original skull and dentition kindly supplied by Dr. J. A. Harris. This is the famous type of "*Homo mousteriensis Hauseri*" that was excavated at Le Moustier in the Vézère Valley, France, in 1908 and described by Klaatsch (1910). It was associated with flint implements of earliest Mousterian age (Osborn, 1915, p. 222). The individual was a young male, judged to be about sixteen years old, with the third upper and lower molars of both sides nearing the period of eruption. The left permanent canine was impacted, and is preserved in the jaw, the deciduous canine being still in place The dentition of this remarkable specimen was briefly noticed by Klaatsch (1910) and more carefully described by Adloff (1910) but neither of these authors mention the fact that the little worn crowns, especially of the cheek teeth, retain many highly important primitive or simian characters.

The dentition as a whole (*fig. 324*) is distinctly macrodont, though not nearly as large as that of the Talgai youth. The large, wide *central upper incisors* have a sharp, flat cutting edge, the right central apparently showing a faint trace of the denticulation so often seen in anthropoid incisors. The cutting edge of the left central incisor has a slightly indicated apex, a remnant of the original apex in more primitive forms. As seen in side view, the long roots of the two central incisors are markedly inclined backward, in accordance with the very strong prognathism of the upper jaw. The labial face of the centrals is gently convex in the middle, flattened below and strongly convex at the sides. As seen in front view the sides of the central incisors converge rapidly toward the neck and there is a marked excess in the transverse diameter of the lower end of the tooth. But the central incisors are not as wide as they are in many chimpanzees and there is less excess of the transverse diameter of the lower end. The lingual surface shows a slight folding around at the sides in continuation with the cutting edge, so that if the tooth

were much worn it would approximate the shovel-shaped section seen in the Krapina men and in various modern races, but there is little if any fossa or concavity on the lingual face. The basal tubercle (tuberculum dentale) seen in many anthropoids is represented by a wide eminence, the broadly convex surface of which is interrupted by one or more vertical grooves, and on the left central by a feeble trace of the median ridge of anthropoids and of primitive human incisors. Thus the central upper incisors are of quite low human type, clearly allied in form especially to those of chimpanzees and gorillas, but differing in the smaller size of their roots and in their decidedly less protruding or prognathous form and position.

The *lateral upper incisors* differ from those of chimpanzees and gorillas in their alignment, since their labial surface faces obliquely outward rather than forward. This is correlated with the loss of the diastema between the lateral incisor and the canine, and with the reduction in size of the lower canine, the tip of which is no longer thrust between the lateral upper incisor and the upper canine. The roots of the lateral upper incisors are much smaller than those of the centrals. The whole tooth, crown and root together, is curved well backward, lying behind the central incisor and in front of the canine. The lower part of the labial surface differs from that of most apes in being nearly vertical instead of being inclined forward; the upper part, on the other hand, slopes upward and backward toward the recumbent root. As seen from in front, the labial surface has its sides less sharply divergent than in the centrals. On the left side the labial surface is higher, narrower and less divergent toward the lower end than on the right.

The loss of a diastema between the lateral incisor and the canine has been one of the conditions that has permitted the lateral incisor to become an intermediate in form between the central and the canine. At least in most of the great apes, on the other hand, the lateral incisor is widely different in form from the canine—as a rule much more primitive, more like the lateral incisor of the gibbons, of *Propliopithecus* and the lower primates. Hence the lateral upper incisor of the Mousterian youth of Upper Pleistocene age is in a far more advanced stage of evolution than that of typical modern anthropoids. This is especially conspicuous on the lingual view of

the tooth; on the right side this is provided with a deep central fossa, a prominent cusp-like tuberculum dentale which is connected with the greatly thickened cingulum, which, in turn, runs respectively to the "mesial" and "distal" borders, the whole arrangement being a notable advance toward the deeply fossed lateral incisors of certain existing Hominidæ. That this relatively high specialization should be attained as early as Upper Pleistocene times is in no way surprising, in view of the fact that some other Pleistocene mammals are actually in a more advanced stage of evolution than that which is preserved in their more conservative modern relatives. The fact of this specialization by no means excludes the Hominidæ from relatively close relationship with the existing anthropoids, which have usually retained a more primitive condition of this tooth, while at the same time they have specialized in other ways, such as the extreme width of the central incisors.

There are numerous examples of convergence in form between adjacent teeth, as when the lower canines have been taken over into the incisor series (e.g., lemurs, ruminants) or when an upper canine has become premolariform (e.g., *Saghatherium*). Adloff and other writers, neglecting such well-founded palæontological facts and noticing in the Mousterian youth and other dentures the structural transition from the central upper incisors to the laterals, to the canines and thence to the premolars, assume that it proves that all the teeth have acquired their existing form through the transformation of one ground plan (Adloff); only we have a marked divergence of opinion as to what that ground plan was, from the double triconodont plan of Bolk to the "biscuspid" plan of many authors. *But to search among modern and extinct Hominidæ rather than among the theromorph reptiles for traces of the "original ground plan" of the human dentition, is to commit an anachronism, the enormity of which is measured by the time interval between the Permian and the Pleistocene!*

The *upper canines* of the Mousterian youth are approaching the bicuspid pattern in the form of their crowns, but their roots retain much of the anthropoid heritage, since they are large and long and project upward above those of the premolars; they are also inclined backward, but to a less degree than those of the incisors. The crowns are unlike those of female chimpanzees, but could be derived

from them by a marked vertical shortening, so as to reduce the tip nearly to the level of that of the anterior premolar. Allowing for differences in wear, the crown of the canine is more abbreviate vertically than that of the Piltdown canine (which may be an upper). On the whole the crown of the upper canine is decidedly more like those of Verneau's Grimaldi dentition (1916, *fig. 23*), of Adloff's native of New Britain (1908, Taf. III), and of certain Chinese and Indian dentures in the American Museum of Natural History. *Here then is the greatest difference between the anthropoid type of dentition and that of the Mousterian youth. In the view of many, this difference will doubtless far outweigh the innumerable characters which link the existing anthropoids and man as divergent descendants of the "ancient anthropomorphous stock."*

The lingual surface of the upper canine is distinguished by the unusually strong development of the basal tubercle, which has been derived (as shown by comparison with more primitive Primates) through the upgrowth of the middle portion of the basal cingulum, as has so often happened in the premolar teeth of many phyla of mammals. The cingulum, as in the incisors and premolars, is continued downward and merges with the "mesial" and "distal" (anterior and posterior) edges of the crown—a direct advance upon conditions observable in the canines of female chimpanzees. A prominent medial ridge runs downward on the lingual surface of the canine from the basal tubercle to the conical tip. The homologue of this ridge may readily be identified in the upper canines of various anthropoids of both sexes. As may be seen by articulating the cast of the lower jaw with that of the upper, the internal spur (tuberculum dentale) of the upper canine would assist in holding the food against the upward thrust of the lower canine and anterior lower premolar; it comes nearly opposite the line of contact of these two teeth It is plainly analogous with the internal spurs (deuterocones, inner cusps) of the true premolars, which cusps press the food against the talonid fossæ of the lower premolars.

The lower incisors and canines of the Mousterian youth are as well preserved as the upper and fully as important from an evolutionary viewpoint. The *lower dental arch* is essentially similar to that of the Heidelberg man and very unlike those of anthropoids, prob-

ably as a result (a) of the reduction of the canines, (b) of the more vertical position of the incisors, and (c) of the widening of the intercondylar diameter. Although the crowns of the *lower incisors* are nearly vertical, and meet their opponents of the upper jaw in an edge-to-edge bite, the roots are inclined gently forward, producing a moderate alveolar prognathism, the effect of which is heightened by the lack of a forwardly projecting bony chin.

The *central lower incisors* are distinctly smaller than those of typical modern anthropoids and have the wearing edges much narrower transversely. On the other hand, they are much larger than those of most modern Hominidæ. The cast shows no trace of the median ridge on the lingual face of the central lower incisor, which is frequently prominent in the homologous teeth of anthropoids; nor is this ridge shown in the Krapina specimens (Kramberger, Taf. VII, fig. 2a), nor do I find it in various modern human specimens examined. (Its presence in the lateral lower incisor is noted below.)

The *lateral lower incisors* of the Mousterian youth are considerably larger and wider than the centrals. They differ from those of modern chimpanzees, gorillas, orangs and gibbons in that their edges lie on a plane which is little if any above the general plane of the molar crowns, while in anthropoids the plane of the incisors lies much above that of the molars. This relation in the Hominidæ is partly associated with the reduction in size of the canines. In connection with the lack of a diastema and the relatively small size of the canines, the wearing surfaces of the lateral incisors are expanded laterally and sharply truncate all across the crown, whereas in modern anthropoids the lateral edge of the lateral incisor slopes downward. Very little is known of the form of the crown of the lateral lower incisors in fossil anthropoids, but there can be no doubt that in recent anthropoids the general form of the crown of this tooth is on the whole more primitive, more like the conditions in recent and fossil lower primates (e.g., *Oreopithecus*, *Dolichopithecus*). Hence the truncate form of the wearing edge of the lateral incisor of the Mousterian youth and of all other Hominidæ is without doubt a distinctively human trait, but derived from the more primitive conditions in the anthropoids.

The lingual surface of the lateral lower incisor bears a distinct median keel, confluent below with the median tubercle, which, as in the upper incisors, is continued laterally and medially into a marginal rim running up toward the wearing surface of the crown. The median keel and bordering rim are less sharply defined than in many anthropoids examined. In the Mousterian youth the keel seems to fade out before it reaches the wearing edge, whereas in many anthropoids and even in some modern Hominidæ it runs up to the wearing edge and is continuous with the middle cusp or tip of the crown. The outer or labial surface of the incisor crown shows little if any tendency to develop a corresponding median keel, as it does in many anthropoids.

The *lower canine*, as shown on the right side of the jaw of the Mousterian youth, tends to be aligned with the incisors rather than with the premolars, as it is in anthropoids; its large, forwardly-curved root and backwardly-curved crown as seen in side view, enhance its resemblance to the incisors. It resembles the incisors also in the vertical depth of its labial surface and, when the lower jaw is articulated with the upper, one see clearly that the lower canine aligns itself with the incisors in function as well as in position. On the other hand, the obtusely-pointed form of its tip suggests the anterior premolar. The lingual surface shows a prominent basal tubercle and a wide median ridge running up to the apex. The basal cingulum is continued upward into the "mesial" and "distal" borders of the crown. That this raised rim as well as the basal tubercle have arisen from the cingulum, and become confluent with the median and lateral borders of the crown, is proven first by comparing these structures in the Mousterian youth and other Hominidæ with the plainly homologous elements in the Simiidæ, and secondly by following these structures down through the lower primates (e.g., *Oreopithecus*, *Mesopithecus*, *Parapithecus*) to the highly primitive conditions in Eocene lemuroids.

From the mixture of "incisor" and "premolar" characters of the lower canine in the Mousterian youth and other Hominidæ, we should assuredly not draw any such inference as that in the ancestors of the Hominidæ all the teeth were once much alike in form or that they were much like the bicuspids. To do so would be to neglect the important

and well established principle that adjacent teeth often tend to become alike.

The crown of the lower canine of the Mousterian youth, as of all Hominidæ, doubtless represents a shortened derivative of a crown much like that of the lower canine of *Dryopithecus*, which has a pointed tip and faces laterally rather than antero-laterally. If the remote ancestors of the Mousterian youth did not have a canine of more normal simian form, how are we to account for the innumerable ties of structural and genetic affinity of man with the primitive giant-ape stock? That the Hominidæ have not been derived from a *Parapithecus*-like stock before the enlargement of the canines, is indicated by the relatively close resemblances of the premolars and molars of the Mousterian youth to those of such advanced anthropoids as *Dryopithecus* and the chimpanzee.

On the left side the permanent canine is impacted and the small *deciduous canine* is still in place. Its tip, although worn, was never high, and its basal tubercle is relatively quite large. This fact may lend further color to the rather widespread view that the canine of the ancestral Hominidæ was a sort of middle term between the incisors and premolars. But those who assume that the deciduous dentition is more primitive (the contrary can be shown in some cases!) do not reflect, first, that a suckling mammal will rarely if ever have the muscular power to fight as vigorously as an adult and hence it would have no need of enlarged canines; and secondly, that for various reasons (cf. page 168 below) the deciduous dentition, instead of repeating adult ancestral history, in each case follows its own line of evolution, which it is true often parallels that of the permanent dentition in many but not all respects. Hence the proper object of comparison for the deciduous canine of the Mousterian youth is not the adult but the deciduous canine of various anthropoids. And in fact we find that it bears some resemblance to the deciduous canines of anthropoids but differs in the lowness of the crown and in the pronounced development of the basal tubercle, both progressive characters of the Pleistocene Hominidæ.

The *upper premolars* are distinguished by the more pithecoid characters of their crowns, as may be seen in comparison with those of *Dryopithecus punjabicus* (*fig. 251*), or even with those of modern chimpanzees (*fig. 275*) and gorillas (*fig. 276*).

Along with these resemblances there are certain notable and important differences due to the more advanced stage of evolution of the Mousterian youth as compared with most known anthropoids. In *Dryopithecus punjabicus* (*fig. 251*) each upper premolar, as figured by Pilgrim (1915, pl. 3), bears on the surface of the crowns three distinct fossæ which may be named, respectively, the anterior, the middle and the posterior fossa. The middle fossa is well separated from its neighbors by two sharp transverse ridges, lying respectively in front of and behind the middle of the tooth, and connected on the buccal side with the main external cusp and on the lingual side with the internal cusp. These three fossæ are more or less distinctly developed in all modern anthropoids examined by me, but sometimes, as in a certain orang (Amer. Mus., no. 19,548) the transverse ridges are low and not very conspicuous, the central fossa is small and is represented by a pit or fissure which on the right anterior premolar is extended antero-posteriorly, dividing the crown into lingual and buccal moieties and tending strongly to obscure the more primitive arrangement.

In the upper premolar of the Mousterian youth one may easily identify the anterior and the posterior fossæ, but in the cast only a trace of one of the transverse crests is indicated, while the middle transverse fossa is no longer clearly identifiable, the anterior and posterior fossæ being connected by a narrow isthmus, so that there is now a division of the crown into buccal and lingual moieties; although the resulting antero-posterior isthmus is not as fissure-like as it is in more modernized dentures. In the second upper premolar the anterior and the posterior transverse fossæ are still strongly marked, but the two transverse crests have apparently united into one, and they are interrupted in the middle of the tooth, so that here again there is a beginning of the division of the crown into buccal and lingual moieties.

That the foregoing is the correct interpretation of the morphology of the upper premolar crowns of the Mousterian youth is indicated in several other primitive human dentures, as well as in the anthropoids. In a palate of the Krapina race, figured by Adloff (Taf. VIII, *fig. 33*), the posterior upper premolar shows clearly the anterior and the posterior fossæ, together with a vestige of the buccal

half of the middle fossa and of the paired transverse crests; the antero-posterior isthmus-fissure is in an early stage of development. In the anterior upper premolar of a Melanesian (New Britain) child, figured by Adloff (Taf. V, *fig. 19a*), the anterior fossa is very sharply defined anteriorly by a bowing out of the border of the crown (as in anthropoids) and posteriorly by a sharp transverse crest which appears to represent the anterior one of the transverse pair of anthropoids. What is apparently homologous with the middle fossa of anthropoids is in this tooth greatly enlarged, the posterior transverse crest being crowded back toward the rear end. The posterior fossa is also well developed, lying beind the last-named crest. Again, in the very large palate of a male native of New Britain, figured in Adloff's Taf. IV, *fig. 18a*, the premolars show clearly the anterior and the posterior fossæ; but while both premolars of the left side bear remnants of the pair of transverse crests, the anterior premolar of the left side has so deep an anteroposterior isthmus that no trace of the crest shows, at least in the figure. *The "Mousterian youth" and these other relatively primitive dentures therefore reveal to us some of the steps by which the modernized bicuspid crown pattern has very probably been attained; namely, by the loss of the paired transverse crests and middle fossa and by the substitution of an antero-posterior fissure or isthmus connecting the anterior and the posterior fossæ.*

The buccal roots of both premolars, so far as exposed, are single and therefore probably represent a complete fusion of the two outer roots of Miocene anthropoid premolars. Even in modern human races the premolars occasionally have two outer roots (Wortman, 1886, p. 443).

The *lower premolars* are very reminiscent of anthropoid conditions. Each one bears on its lingual side prominent anterior and posterior fossæ separated by transverse ridges. The anterior fossa of the first bicuspid as seen from above is triangular in outline, with the apex directed forward. The posterior fossa of the second bicuspid is much larger than the anterior fossa and is plainly homologous with the corresponding fossa of anthropoids.

The more important differences from anthropoids are the following: (1) In correlation with the smaller size of the upper canine, the tip of the first bicuspid of the Mousterian youth is lower than that of

anthropoids and the antero-external face is but slightly flattened. (2) In the second bicuspid, the apex and the trigonid (anterior) fossa are reduced nearly to the level of the posterior moiety or incipient talonid. (3) Both bicuspids are much wider in proportion to their antero-posterior length than are the homologous teeth of anthropoids. (4) The first bicuspid is turned somewhat mesially toward the incisor-canine arch, whereas in anthropoids, which have a longer, less widened and shortened jaw, the first bicuspid is antero-posterior in position. (5) The roots of the bicuspids are crowded and reduced in number, whereas in anthropoids they are unreduced. *In all these, as in many other particulars, the anthropoids, especially Dryopithecus, are plainly more primitive, less different from still older and lower primates, while the Mousterian youth represents a highly progressive family (Hominidæ) in which the jaws have been greatly shortened, the intercondylar diameter excessively widened, the molars and premolars widened transversely and shortened antero-posteriorly.*

Upper molars. The first upper molar is perhaps the most primitive and conservative of all the upper teeth. The general contour as seen from above is somewhat rhomboid, with the hypocone projecting well backward. The primitive crest connecting the protocone with the metacone is well developed and the transverse fissure separating the adjacent bases of the para- and metacones is almost as sharply defined as it is in the homologous tooth of *Dryopithecus punjabicus*. The cleft separating the hypocone from the protocone is likewise deep and sharp. Thus, as in the last-named anthropoid, the surface of the first upper molar presents four transverse fossæ separated by oblique crests: the first, lying immediately behind the anterior border, presses the food against the protoconid of the lower molar, while the oblique ridge behind it fits between the proto- and the hypoconid; the second or central fossa of the upper molar receives the hypoconid of the lower molar, while the ridge behind it fits between the hypoconid and the hypoconulid of the lower molar; the third fossa lies on the lingual side of the crown between the proto- and the hypocone, and receives the transverse crest on the entoconid; the fourth fossa lies buccad to the hypocone and receives the hypoconulid of the lower molar.

These and other fundamental agreements with the primitive anthropoid type of upper molar are naturally accompanied by numerous important differences, perhaps acquired by the human ancestors of the Mousterian youth in the immense interval between the Upper Pleistocene and the Miocene.

(1) In the first place the first upper molar bears a distinct but not large Carabelli cusp on its antero-internal corner, but neither in this skull nor in the Krapina specimens figured by Adloff and by Gorganovic-Kramberger does this cusp attain sufficient size to reach the general wearing level of the crown. Indeed the cusp itself in the Upper Pleistocene Hominidæ is plainly a derivative of the basal cingulum, which in many anthropoids has a pronounced development on the antero-internal corners of the crown.

Many authors (including Cope, Adloff, Osborn, Schwalbe and Jeanselme) have recognized that the Carabelli cusp (tuberculum anomalum) has been derived from the cingulum. But, from the absence or great rarity of this cusp in anthropoids (Adloff has figured it in a single gibbon), from its prevalence in the adult first molar of the Krapina men and of many lower existing races, and from the high frequency of the cusp in the second milk-molar of modern races, Adloff (pp. 125–129) concludes that the possession of a Carabelli cusp is a primitive human character which sharply separates man from the anthropoids.

From this and certain other considerations Adloff concludes that man and the anthropoids are independent derivatives of different and wholly unknown pre-Eocene mammals. I, on the other hand, while recognizing that the Carabelli cusp (although in an imperfectly developed stage) was already attained by some Pleistocene Hominidæ, conclude that *the presence of the external cingulum at the antero-internal corner of the first and second upper molars in primitive anthropoids, and its occasional development into a Carabelli cusp in the gibbon, provide us with the starting point for the human line of specialization, and that a comparison of the incipient Carabelli cusp in the Mousterian youth with the vigorous development of the antero-internal cingulum in a certain chimpanzee (Amer. Mus., no. 10,276) only serves to emphasize the relatively close structural and phyletic relationship between these two genera.*

Other important differences of the upper molars of the Mousterian youth from those of modern chimpanzees and gorillas in the same stage of wear are the following: (2) The crowns as a whole are more hyposodont (taurodont). (3) The principal cusps are lower, more obtuse. (4) The small accessory cusp, which in many chimpanzees lies behind the metacone, is absent (it is present in *Dryopithecus rhenanus* but apparently not in *D. punjabicus;* on the other hand, it is present in m^1, m^2, of a certain Indian from Peru). (5) The postero-external borders of m^1, m^2 slope backward obliquely, while in the *Dryopithecus* they are more transverse. (6) The hypocones of m^1, m^2 are relatively larger and project further inward than they do in some modern chimpanzees and gorillas. (7) The hypocone of m^2 in the Mousterian youth does not project downward to the level of the protocone, whereas in modern chimpanzees and gorillas the homologous cusp of m^2 reaches or even goes beyond the level of the protocone (in m^2 of *Dryopithecus punjabicus*, however, the hypocone is lower than the protocone). (8) The surfaces of the crown of m^1, m^2 are less delicately furrowed than is the case in many modern chimpanzees, and apparently less than in *Dryopithecus rhenanus*. In the Krapina specimens (Gorjanović-Kramberger, Taf. XIII), however, the upper molars have a few delicate furrows in addition to the main ones. In view of the wide range of variation in the degree of furrowing in Hominidæ and Simiidæ, no great phylogenetic importance may be ascribed to this character. (9) In m^1, m^2 a distinct cuspule at the junction of the oblique protocone crest with the anterior cingulum is present in *D. rhenanus*, *D. punjabicus* (Pilgrim, Pl. 2, *fig. 14*) and in some gorillas and chimpanzees. In the Mousterian youth a similarly placed cuspule is indicated in the cast of the second right upper molar, but is hardly distinguishable from the protocone crest in the cast of m^1, of both sides. In one of the Krapina dentures figured by Gorjanović-Kramberger (1906, Taf. IV, *fig. 2*), the oblique protocone crest is angulate but apparently bears no distinct cusp. In m^2 of another Krapina specimen, figured by Adloff (Taf. VIII, *fig. 3*), the angle of the oblique protocone crest is more or less cusp-like. Cusps in this position, namely, buccad to the locus of the Carabelli cusp and on or near the anterior rim of the tooth, are shown on m^1, m^2, and m^3 in Adloff's figure of a palate of a native of

New Britain (Taf. VI, *fig. 28*) and in m^1 of a certain Swabian skull (Amer. Mus., $\frac{99}{4556}$). (10) The two outer roots of m^2 of the Mousterian youth are straighter and less divergent than are those of *Dryopithecus punjabicus* and many modern anthropoids. (11) The third upper molar of the Mousterian youth has the hypocone smaller but projecting further inward than in *Dryopithecus punjabicus* (Pilgrim, pl. 2, *fig. 5*). In these characters it agrees with one of the Krapina specimens (Gorj.-Kramberger, Taf. XIII, *fig. 3*). (12) The third upper molar of the Mousterian youth, as in all Hominidæ, was delayed in its eruption until long after the other upper teeth, especially canines, were in place; whereas, as in all modern Simiidæ and probably also in *Dryopithecus fontani*, the third molars came into place quite early. But, as I have shown elsewhere, a very early eruption of the third molar is surely a primitive character for primates as a whole, and the progressively delayed reduction in the Hominidæ is surely a specialization which is not to be expected in their simian ancestors.

The *lower molars* (especially m_1, m_2), as already stated, retain much of the primitive *Dryopithecus* pattern; and as we pass from m_1 to m_3 we observe the progressive obliteration of this pattern, although the cruciform or +-shaped pattern is not fully attained. The first molar, as in all other Hominidæ, is the most conservative. The molars differ from the primitive anthropoid type in the following characters:

(1) They are all much widened transversely, the width across the posterior moiety being relatively far greater than in typical anthropoids. (2) As we pass from m_1 to m_3 the "taurodont" condition (see above, p. 140) increases. (3) The hypoconids are larger and the hypoconulids smaller than in typical anthropoids. (4) All the main cusps are lower and blunter, so that the general wearing surface of the crown would have been nearly flat when much worn. (5) The antero-posterior length of m_1, as compared with the combined length of the two bicuspids, is much greater in the Mousterian youth and in other Hominidæ than in *Dryopithecus rhenanus*, as shown in the following comparative table:

Length of m_1 ÷ length of $p_3 + p_4$

Dryopithecus rhenanus ♂	0.57
Mousterian youth ♂	0.75
Illinois Indian ♂	0.88
"Hindoo" (South India) ♂	0.84
"Bedouin" ♀	0.75

This means that in the primitive anthropoid, *Dryopithecus rhenanus*, the premolars are relatively long, the jaw itself being elongate. In the Mousterian youth the space for the premolars has been decidedly shortened, while the first molar is relatively and absolutely larger. This tendency is still more pronounced in the male Indian jaw, which has a very large first molar. But when we come to the small-jawed female Bedouin, the first molar has lost some of its superiority in size over the small premolars and the ratio falls to 0.75.

(6) In *Dryopithecus rhenanus* the second lower molar is decidedly larger than the first, but in the Mousterian youth, and still more in modernized human dentitions, the second lower molar decreases in relative size as shown below:

Ant.-post. length of m_2 ÷ ditto of m_1

Dryopithecus rhenanus ♂	1.95
Mousterian youth ♂	1.00
Illinois Indian ♂	0.90
"Hindoo," So. India ♂	0.86
Bedouin ♀	0.99

Dentition of the Krapina sub-race

The dentition of the Krapina sub-race of *Homo neanderthalensis* has been described and figured by Gorjanović-Kramberger (1906, pp. 181–207). The central upper incisors are of great interest because they afford what is apparently a stage in the evolution of the shovel-shaped or mongoloid condition, the cutting edge being folded around at the sides and being confluent with prominent rims which lead upward to the large basal tubercle. The latter is subdivided by clefts into two ridges. Both in the central and lateral incisors the cutting edge of certain unworn specimens is more or less notched near the middle; and from this fact, as well as from the division of the basal tubercle and from the occasional grooving of the anterior root, Gor-

janović-Kramberger infers (p. 206) that each human incisor has arisen from the fusion of two incisors. Similar considerations lead him (p. 207) to conceive an upper premolar as arising from the fusion of two canine-like teeth, while the molars are regarded as arising from clusters of $4\frac{1}{2}$ or more cusps. This application of the well-known "concrescence theory" will be considered below. Meanwhile it may be noted that according to Gorjanović-Kramberger's view the remote ancestors of the Krapina race must have had not less than 155 teeth in the adult dentition! On the whole the dentition of the Krapina subrace agrees in essentials with that of the Mousterian youth, except that the crowns of the lower molars are much wrinkled and furrowed and the main cusps of all the molars are lower and less distinct. The "fovea anterior" of the lower molars is plainly the last remnant of the trigonid fossa of anthropoids.

Conclusion as to the origin and relationships of the Neanderthal group

To sum up as to the origin and relationships of the Neanderthal group: It has been suggested (Smith Woodward, 1900) that even the lowness of the forehead and excessive development of the supra-orbital tori of the neanderthaloids may be a secondary gorilloid sort of specialization along with the taurodont condition of the molars; and from the palæontological-archæological evidence it has indeed been shown that the Crô-Magnons of western Europe, which were of *Homo sapiens* type, did not evolve out of the neanderthaloids but invaded their territory and overwhelmed and partly absorbed them. Nevertheless I think there is still something to be said in favor of those (e.g., Hrdlička) who regard the neanderthaloids, or some of them, as structural ancestors—primitive or perhaps archaic types surviving into a later epoch—of the higher races. For even the extreme condition of taurodontism is found in company with a large series of characters which most authorities would regard as very low (e.g., small development of the front part of the brain, slight downward bending of the prepituitary plane, enormous size and width of the nose, flat articular eminence, gorilla-like cervicals, primitive form of astragalus, etc., etc.).

If we assume that high foreheads, small jaws and other "high" characters are really primitive for the Hominidæ, then of course the

neanderthaloids are highly specialized. But there are several items of evidence to which perhaps sufficient importance has not been attached. First, the Heidelberg jaw is admittedly very ancient and nobody has yet claimed that its lack of a chin or the great width of its ascending ramus are specializations that rule it out from structural ancestry to the higher types. And yet it will be widely admitted that the Heidelberg skull was probably of a pre-neanderthaloid and more *Pithecanthropus*-like type. But the crown patterns of the lower molars of the Heidelberg jaw are also generally recognized as of primitive human type, although the molars were also at least subtaurodont in the depth of their pulp cavities and shortness of their roots. Secondly, the dentition of the "Mousterian youth," as shown above, retained a number of extremely primitive or simian characters in the patterns of the cheek teeth. Here again we find *very primitive features in the crown pattern associated with at least a moderate degree of taurodontism.*

If the Piltdown lower jaw be associated with the skull, as maintained by many authorities, it will provide another example of the coexistence of primitive features in the jaw and dentition, with a deeper pulp cavity than is common among recent jaws. In a jaw of a modern European figured by Adloff (1910, plate 2, jaw H) the pulp cavity is much deeper and larger than in ordinary teeth. From all this I therefore conclude that *at least a moderate degree of taurodontism may be a primitive character for the Hominidæ.*

Adloff concludes (1910, p. 144) that the newest discoveries of Palæolithic races have brought no conclusions which could be of significance for our knowledge of the development (evolution) of the human dentition and that they only furnish proof that the human dentition has undergone no significant change during the time in which the jaw itself has passed through important modifications. In view of the facts set forth here, I, on the contrary, conclude that *the dentition of the "Mousterian youth" and of the Krapina people afford important additional evidence for the conclusion that the human dentition has been evolved from a primitive anthropoid type and has undergone highly significant changes (especially in the crown patterns of the premolars and molars) during the time in which the jaw itself has been evolving toward the "modern" or high type.*

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Neither the writer's knowledge nor the available space are sufficient for an adequate treatment of the morphology of human jaws and teeth, or for a detailed account of racial characters of the dentition. Nevertheless a few notes on these subjects may now be submitted, together with a conspectus of the species, races and subraces of the Hominidæ, for the purpose of completing the main outlines of this review of the evolution of the human dentition.

Fusion of premaxilla and maxilla

With regard to the premaxillary bone, Wood Jones (1918, p. 36) has emphasized its very early fusion with the maxilla in man and states that: "In all the monkeys and apes, as in all other mammals, this premaxillary element is mapped out on the face by suture lines marking its junction with the maxillary bones. In man alone has an alteration of the method of growth of this region led to a loss of the individuality of the premaxillary element. This is a human specific character. From all orthodox teaching we should therefore expect it to be very late in its appearance in the human embryo; we should hardly look for it earlier than the fifth month. As a matter of fact this character is established as soon as ever the future bones of the human face are first represented as cartilaginous nuclei.

"It has become a character of the human embryo at a stage when the development has proceeded so little way that the future being is no longer than ten times the diameter of an ordinary pin's head. Such a finding, in the development of any animal, forces the conclusion that a distinctive feature, so early acquired in embryology, was early acquired in history, and that the species must be very old indeed. It therefore seems possible that not only is man an excessively primitive animal, which originated right at the base of the Primate stem, but he probably also acquired his specific characters in an extremely remote past."

When writing that "in all the monkeys and apes, as in all other mammals, this premaxillary element is mapped out on the face by suture lines marking its junction with the maxillary bones," Wood Jones could hardly have had before him many specimens of anthro-

poid skulls. In a young female chimpanzee skull (Amer. Mus., no. 51,211), a wild specimen with the deciduous canines and molars in place, I find only the faintest indication of the premaxillary-maxillary suture on the face, although remnants of the suture are visible on the palate; and in various adult anthropoids of all genera the fusion of the premaxilla with the maxilla seems complete, so that the anthropoids have attained in this character a condition that in the light of other evidence may reasonably be regarded as prehuman. Although the premaxilla of man does begin to fuse with the maxilla as early as the seventh week (Ferber, 1919), this is only in keeping with great acceleration of other characters (e.g., of the foot) in human development.

The concept of the biogenetic law invoked by Wood Jones to disprove the relationship of man with the anthropoids happily belongs to a past century. *It is nowadays realized by many embryologists that at least in many cases the order of appearance of structures in ontogeny by no means corresponds to their order of evolution.* It would be interesting to know whether the fusion of the premaxilla with the maxilla is as early in individuals with large prognathous incisors as it is in those with small incisors and orthognathous face.

The concrescence theory and the origin of human incisors

The ontogeny of the teeth has afforded innumerable pitfalls for those who have not realized that *in modern mammals developmental processes are adjusted primarily to relatively modern requirements and conditions.* Various parts of the teeth, such as cusps, cingula, etc., appear as more or less separate elements and afterward fuse into an undivided whole. But as the presence of many ossific centers in the developing humerus by no means indicates that phylogenetically the humerus is a composite of as many separate bones, so also a similar reasoning applies to the teeth; because the palæontological, comparative and taxonomic evidence is cumulative that the normal crowns of mammalian teeth have evolved by differentiation, not by concrescence.

By this time the theory of concrescence in all its varied forms should be as dead as the Copernican theory, but, strange to say, it is still cherished by many European writers. A few of the many fundamental objections to the theory are as follows:

(1) It neglects the well established principle cited above, namely that dental development in modern mammals is largely directed toward the production of highly specialized dental forms with but little "recapitulation" of remote ancestral history. For example, the laminæ of elephant molars appear to form separately and later to coalesce, but the palæontological evidence shows clearly that these many-plated molars have arisen phylogenetically, not through concrescence but by differentiation of less complex molars.

(2) The theory makes the wholly unwarranted assumption that because individual teeth often become wholly or in part divided, therefore the divided parts represent the original components of an ancient concrescence. This assumption is often contrary to evidence. For example, in the special case of the Krapina teeth cited above, the grooving of one of the roots, the notching of the crown of the incisor, etc., are supposed by Gorjanovic-Kramberger to indicate that these teeth have arisen from the fusion of originally separate elements. From what he assumes as to the number of originally separate teeth entering into the composition of the incisors, canines, premolars and molars, it follows directly that the dental formula of the remote ancestors of the Krapina race must have been as follows: $I^{2(\times 2)}_{2(\times 2)}$ $C^{1(\times 2)}_{1(\times 2)}$ $P^{2(\times 2\times 2)}_{2(\times 2\times 2)}$ $M^{3(\times 4.5+)}_{3(\times 4.5+)}$, or a minimum number of 155 teeth in all! But the palæontological, taxonomic and morphological evidence is cumulative that the Krapina race belongs to an order of mammals which, from a very remote antiquity (Lower Eocene), had a dental formula never exceeding I^2_2 C^1_1 P^4_4 M^3_3, or 40 teeth in all. The Old World or catarrhine division, to which the Hominidæ belong, by the elimination of the first two premolars in both jaws, early reduced the formula to I^2_2 C^1_1 P^2_2 M^3_3, or 32 teeth in all, the reduction occurring not by concrescence but by reduction and final elimination of the first and second premolars.

(3) The concrescence theory assumes, as atavistic, variations which are often plainly teratological. For example, a recent author (Pohle, 1900) records an actual case of concrescence of adjacent teeth in two modern musteline carnivores as evidence for the origin of teeth by concrescence. But from palæontological, taxonomic and comparative evidence it is highly probable that the variation above described is teratological, not atavistic.

The special form of the concrescence theory advocated by Bolk (1913, 1914) is based, like other forms of the theory, chiefly upon an erroneous phylogenetic interpretation of certain ontogenetic facts. Bolk's excellent contributions to our knowledge of the facts of development are overlaid by his peculiar hypothesis that every tooth, from the incisors to the last molars, represents a "dental family" of two (or more?) successional tooth germs, and consists of two parts: an outer, labial or buccal part, called the protomere; and an inner or lingual part, the deutomere. From various indications among modern mammalian teeth, proto- and deutomere are each inferred to be potentially equivalent to a triconodont crown, so that every tooth potentially or actually carries six primary cusps!

But it has already been shown in previous parts of this work that, *in the long series of forms that stand in or near the line of human ascent, from the rhipidistian fishes up through the primitive amphibians and reptiles to the mammal-like reptiles, thence through the Mesozoic trituberculates to the Eocene primates there is not one whose incisor, or any other teeth, conform to Bolk's ideal pattern.*

More in detail, not one of the incisors or canines of these Lower Eocene lemuroids, or of any other Paleocene or Eocene placental mammals of any order, approach even remotely the six-cusped stage which Bolk assumes as the starting-point for all the teeth of primitive mammals. This six-cusped stage is a pure inference from his primary assumption that every placental mammalian tooth consists at least of two parts, a protomere and a deutomere, each equivalent to a triconodont tooth. The evidence in the first place is against the derivation of tritubercular teeth from a triconodont type; secondly, the double or even single triconodont form is never apparent in the incisor and canine teeth of any of the mammal-like reptiles, the protodonts or the triconodonts themselves.

The more or less tricuspidate, cingulate incisor and premolar crowns of the galagos, Hapalidæ and Cebidæ, which Bolk refers to, afford no real support to his view. The incisor teeth in most families of mammals are highly adaptive organs, which assume such useful forms and functions as their positions, with reference to the food, to the jaw muscles and to adjacent and opposing teeth, will permit. It is proven from much palæontological and comparative evidence

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With regard to the premaxillary bone, Wood Jones (1918, p. 36) has emphasized its very early fusion with the maxilla in man and states that: "In all the monkeys and apes, as in all other mammals, this premaxillary element is mapped out on the face by suture lines marking its junction with the maxillary bones. In man alone has an alteration of the method of growth of this region led to a loss of the individuality of the premaxillary element. This is a human specific character. From all orthodox teaching we should therefore expect it to be very late in its appearance in the human embryo; we should hardly look for it earlier than the fifth month. As a matter of fact this character is established as soon as ever the future bones of the human face are first represented as cartilaginous nuclei.

"It has become a character of the human embryo at a stage when the development has proceeded so little way that the future being is no longer than ten times the diameter of an ordinary pin's head. Such a finding, in the development of any animal, forces the conclusion that a distinctive feature, so early acquired in embryology, was early acquired in history, and that the species must be very old indeed. It therefore seems possible that not only is man an excessively primitive animal, which originated right at the base of the Primate stem, but he probably also acquired his specific characters in an extremely remote past."

When writing that "in all the monkeys and apes, as in all other mammals, this premaxillary element is mapped out on the face by suture lines marking its junction with the maxillary bones," Wood Jones could hardly have had before him many specimens of anthro-

poid skulls. In a young female chimpanzee skull (Amer. Mus., no. 51,211), a wild specimen with the deciduous canines and molars in place, I find only the faintest indication of the premaxillary-maxillary suture on the face, although remnants of the suture are visible on the palate; and in various adult anthropoids of all genera the fusion of the premaxilla with the maxilla seems complete, so that the anthropoids have attained in this character a condition that in the light of other evidence may reasonably be regarded as prehuman. Although the premaxilla of man does begin to fuse with the maxilla as early as the seventh week (Ferber, 1919), this is only in keeping with great acceleration of other characters (e.g., of the foot) in human development.

The concept of the biogenetic law invoked by Wood Jones to disprove the relationship of man with the anthropoids happily belongs to a past century. *It is nowadays realized by many embryologists that at least in many cases the order of appearance of structures in ontogeny by no means corresponds to their order of evolution.* It would be interesting to know whether the fusion of the premaxilla with the maxilla is as early in individuals with large prognathous incisors as it is in those with small incisors and orthognathous face.

The concrescence theory and the origin of human incisors

The ontogeny of the teeth has afforded innumerable pitfalls for those who have not realized that *in modern mammals developmental processes are adjusted primarily to relatively modern requirements and conditions.* Various parts of the teeth, such as cusps, cingula, etc., appear as more or less separate elements and afterward fuse into an undivided whole. But as the presence of many ossific centers in the developing humerus by no means indicates that phylogenetically the humerus is a composite of as many separate bones, so also a similar reasoning applies to the teeth; because the palæontological, comparative and taxonomic evidence is cumulative that the normal crowns of mammalian teeth have evolved by differentiation, not by concrescence.

By this time the theory of concrescence in all its varied forms should be as dead as the Copernican theory, but, strange to say, it is still cherished by many European writers. A few of the many fundamental objections to the theory are as follows:

(1) It neglects the well established principle cited above, namely that dental development in modern mammals is largely directed toward the production of highly specialized dental forms with but little "recapitulation" of remote ancestral history. For example, the laminæ of elephant molars appear to form separately and later to coa'esce, but the palæontological evidence shows clearly that these many-plated molars have arisen phylogenetically, not through concrescence but by differentiation of less complex molars.

(2) The theory makes the wholly unwarranted assumption that because individual teeth often become wholly or in part divided, therefore the divided parts represent the original components of an ancient concrescence. This assumption is often contrary to evidence. For example, in the special case of the Krapina teeth cited above, the grooving of one of the roots, the notching of the crown of the incisor, etc., are supposed by Gorjanovic-Kramberger to indicate that these teeth have arisen from the fusion of originally separate elements. From what he assumes as to the number of originally separate teeth entering into the composition of the incisors, canines, premolars and molars, it follows directly that the dental formula of the remote ancestors of the Krapina race must have been as follows: $I^{2(\times 2)}_{2(\times 2)}\ C^{1(\times 2)}_{1(\times 2)}\ P^{2(\times 2\times 2)}_{2(\times 2\times 2)}\ M^{3(\times 4.5+)}_{3(\times 4.5+)}$, or a minimum number of 155 teeth in all! But the palæontological, taxonomic and morphological evidence is cumulative that the Krapina race belongs to an order of mammals which, from a very remote antiquity (Lower Eocene), had a dental formula never exceeding $I^2_2\ C^1_1\ P^4_4\ M^3_3$, or 40 teeth in all. The Old World or catarrhine division, to which the Hominidæ belong, by the elimination of the first two premolars in both jaws, early reduced the formula to $I^2_2\ C^1_1\ P^2_2\ M^3_3$, or 32 teeth in all, the reduction occurring not by concrescence but by reduction and final elimination of the first and second premolars.

(3) The concrescence theory assumes, as atavistic, variations which are often plainly teratological. For example, a recent author (Pohle, 1900) records an actual case of concrescence of adjacent teeth in two modern musteline carnivores as evidence for the origin of teeth by concrescence. But from palæontological, taxonomic and comparative evidence it is highly probable that the variation above described is teratological, not atavistic.

The special form of the concrescence theory advocated by Bolk (1913, 1914) is based, like other forms of the theory, chiefly upon an erroneous phylogenetic interpretation of certain ontogenetic facts. Bolk's excellent contributions to our knowledge of the facts of development are overlaid by his peculiar hypothesis that every tooth, from the incisors to the last molars, represents a "dental family" of two (or more?) successional tooth germs, and consists of two parts: an outer, labial or buccal part, called the protomere; and an inner or lingual part, the deutomere. From various indications among modern mammalian teeth, proto- and deutomere are each inferred to be potentially equivalent to a triconodont crown, so that every tooth potentially or actually carries six primary cusps!

But it has already been shown in previous parts of this work that, *in the long series of forms that stand in or near the line of human ascent, from the rhipidistian fishes up through the primitive amphibians and reptiles to the mammal-like reptiles, thence through the Mesozoic trituberculates to the Eocene primates there is not one whose incisor, or any other teeth, conform to Bolk's ideal pattern.*

More in detail, not one of the incisors or canines of these Lower Eocene lemuroids, or of any other Paleocene or Eocene placental mammals of any order, approach even remotely the six-cusped stage which Bolk assumes as the starting-point for all the teeth of primitive mammals. This six-cusped stage is a pure inference from his primary assumption that every placental mammalian tooth consists at least of two parts, a protomere and a deutomere, each equivalent to a triconodont tooth. The evidence in the first place is against the derivation of tritubercular teeth from a triconodont type; secondly, the double or even single triconodont form is never apparent in the incisor and canine teeth of any of the mammal-like reptiles, the protodonts or the triconodonts themselves.

The more or less tricuspidate, cingulate incisor and premolar crowns of the galagos, Hapalidæ and Cebidæ, which Bolk refers to, afford no real support to his view. The incisor teeth in most families of mammals are highly adaptive organs, which assume such useful forms and functions as their positions, with reference to the food, to the jaw muscles and to adjacent and opposing teeth, will permit. It is proven from much palæontological and comparative evidence

that in primitive primates the incisors, like those of other mammals, were provided with a cingulum on the lingual side, which was possibly associated with the alveolar borders of the crown and with the zone of fusion of the crown with the root. The basal cingulum often or usually thickened into a more or less well-marked swelling or tuberculum dentale, and on the sides of the tooth it was continued upward into the cutting edges of the crown. The lingual side of the tooth was often buttressed by a more or less well-defined vertical ridge running up to the tip of the crown. In the very primitive Eocene lemuroids of the family Notharctidæ, the above described condition may be observed not only in all the incisors but also in the canines and anterior premolars; and as we pass backward the premolars become more complex, through the growth of the tuberculum dentale, inward in the upper, backward in the lower jaw, and through the modelling of the median ridge, development of accessory cusps, etc. But in this connection it is important to remember that *the four classes of teeth, incisors, canines, premolars and molars, were more or less differentiated from each other, not only in the earliest Lower Eocene primates but in the vastly older Mesozoic trituberculates and even in the higher mammal-like reptiles.*

From the primitive conditions of the incisors in the Notharctidæ we may securely trace their progressive evolution, starting with *Parapithecus*, the most primitive known member of the Old World series and, passing upward through the conditions preserved in the existing gibbons, to the relatively long-crowned incisors of all the giant anthropoids and of man. In the anthropoids the crowns, especially of the central incisors, often become excessively long, perhaps in correlation with frugivorous-omnivorous habits, and the wearing edges of the centrals become excessively wide. Correlated with the width of the cutting edge and with the development of the strengthening median and accessory ridges, the edges of the central incisors become either denticulate or trifid. In the latter case the middle cusplet is continuous with the median ridge. But this denticulate or cuspidate condition of the edge of the incisors of the chimpanzee has nothing whatever to do with the primitive form of the incisor crown of pre-Tertiary mammals, except in so far as it represents an end stage of specialization. *In man the trifid or trident-*

like condition of the incisors, both in the deciduous and permanent dentures, is clearly related to the conditions observed in the anthropoids and has just as little to do with the original ground-plan of the mammalian teeth.

Now it is a peculiarity of ridges, separate cusps, etc., that as soon as they have established themselves their development tends to be accelerated; and in the case of the notches and cuspules on the surface of the incisor crown, it sometimes happens that one of the clefts becomes rapidly enlarged in ontogeny, extending downward to the base of the crown and giving a twinned or double appearance to the tooth. As we have seen above, such a notch in the wearing edge of one of the Krapina incisors was cited by Gorjanović-Kramberger as evidence of the origin of the teeth by concresence.

A further development of the cingulum and tuberculum dentale, together with a folding around of the wearing edges of the incisor crown, leads to the shovel-shaped or "rim-and-fossa" condition which has been so thoroughly investigated by Hrdlička (1921) and which is prevalent in many primitive races of Hominidæ from the Pleistocene Krapina race onwards.

Origin of human canine teeth

Both the direct palæontological evidence afforded by the Heidelberg and Neanderthal dentitions and the comparative evidence of the dentures of existing races indicate that, if the tips either of the upper or of the lower canines ever projected beyond the level of the cheek teeth, the reduction in size took place at some time anterior to the Middle Pleistocene. The Piltdown race forms a possible exception to this statement; but as the association of the ape-like canine and jaw with the man-like skull still seems doubtful, this evidence may be set aside for the present. Very rarely, in low human races (e.g., *fig. 305*) the tip of the lower canine projects above the level of the premolars, but these cases are so rare, and there is always such danger of confusing abnormal neomorphs with reversions, that they too may be left out of consideration. Add to this the fact that the oldest known members of the Old World series, *Propliopithecus* and *Parapithecus*, both had low-crowned lower canines, and the case for the human races ever having had enlarged canines may seem pretty weak.

Nevertheless there is considerable indirect evidence for this view. In certain mammals (e.g., *Homalodotherium*) the loss of diastemata and the closure of the tooth-row has gone hand in hand with the reduction of the canines to the level of the other teeth. There is little doubt that in the primitive man-anthropoid stock the lower incisors were slightly procumbent and that the vertical or recurved incisors of man are specialized. The increased verticality of the incisors, perhaps correlated in part with a change from frugivorous to omnivorous diet and the rotary action of the mandible, are perhaps unfavorable to the retention of large caniniform canines. The anatomical evidence for a relatively near relationship of man with the gorilla is so overwhelming that it is difficult to conceive the common stem-form as having a man-like lower dentition, especially in view of the fact that in the patterns of the premolars and molars the gorilla is plainly more primitive. Again the form of the lower dental arch in man appears to be derived from the more primitive conditions in *Dryopithecus*, which had pointed lower canines of primitive anthropoid type (*fig. 312*). We have seen that in the case of a certain species of monkey (*fig. 218*) a convergent or closed incisor arch and pronounced diastemata are associated with the small canines of the female, while a wide incisor arch and pronounced diastemata are associated with the large canines of the male, and that in female orangs with small canines the upper dental arch makes some approach to the human form. The anomalous position of the lower canine in higher races, with its tip lying on the lingual side and overhung by the upper lateral incisor and upper canine, is largely due to the loss of the diastema and probably also to the erect position and reduction of the canines. In brief, the larger canines of *Dryopithecus* and female anthropoids are associated with a more primitive form and arrangement of the incisors, of the symphyseal region, of the dental arches and of the muscles of the lips. Conversely, small canines of human form are associated with a complex of conditions which few (except Wood Jones), could regard as primitive. Hence it seems probable, though not demonstrated, that the small canines of man are no more primitive than his other distinctive characters of the dentition.

Supernumerary dental elements and the confusion of neomorphs with reversions

A prolific source of confusion in odontology is the occurrence of supernumerary teeth in man and other mammals, which, being mistaken for reversional phenomena, lead to erroneous inferences regarding the dental formula of the human precursors. The most notable case is the occasional occurrence in man and anthropoids of a fourth molar. But it has already been shown in Part III (p. 423) that the fourth, and even the fifth molar when present, are in all probability neomorphs both in man and in anthropoids, and that the various phyla of the man-anthropoid group are independently acquiring a new growth-power at the posterior end of the dental lamina, as has happened in other groups of mammals (e.g., *Myrmecobius* among marsupials, sirenians, toothed whales, armadillos, *Otocyon*, etc., among placental mammals).

Adloff (1908) infers that in the precursors of man the dental formula was $I\frac{3}{3}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$, and that the dental formula of $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$ has been acquired by man and by anthropoids in different ways and by convergence. But this assumption, which is supported by very little evidence, is contradicted by the enormous number of characters which prove that man and the existing anthropoids are divergent descendants of a common stock having the dental formula of the whole Old World series.

One line of evidence upon which Bolk relies for the support of his theory is the occasional occurrence in man of "paramolars," or small teeth on the buccal side of the upper molars which are sometimes fused with them. The occurrence of these elements is interpreted as a "reversion." But by what right have such variations to be regarded as reversional in spite of the cumulative palæontological, comparative and taxonomic evidence that no such assumed stage ever stood in the line of human ascent? In order to account for the supposed homologies of the "paramolars" and true molars, Bolk assumes that the conditions in the marmosets (which have already lost the third molars) have given rise to the conditions observed in man. But, as already shown in Part III of this work, this assumption is contradicted by weighty taxonomic considerations, since the Hapalidæ

are highly specialized members of the New World series and have only the most distant indirect relationship with the Hominidæ. The latter, as we have seen, are highly specialized members of the Old World series, and there is no substantial evidence that the dental formula of this group since its first differentiation, from some supertarsioids allied to *Parapithecus*, has ever been different from $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$.

The constant mistaking of abnormal or new variations for atavistic reversions, together with a total disregard of taxonomic and palæontological evidence, has been one of the worst sources of erroneous conclusions in comparative anatomy, including odontology, and has contributed greatly to the present confusion in opinion as to the evolution of the human dentition and to the low regard in which morphology is held by many modern biologists. This unfortunate mistake has been well exposed by Raymond C. Osburn (1912) in a paper which seems to have been overlooked or little appreciated by many odontologists. In this paper Osburn reviews the evidence showing that many dental variations cannot possibly be considered as atavistic, because the known earlier stages of dental evolution are wholly unlike the assumed stages.

Those who mistake cænogenetic developmental conditions, secondary simplifications, and abnormal variations for atavistic reversions seldom hesitate to assume the existence of wholly unknown orders and families (having the peculiar characters required by their hypotheses) rather than adjust their hypotheses to the known facts of palæontologic history. For example: Chiavaro, (1920), after noting certain cases in which the tuberculum dentale of human incisors was exceptionally developed, and after comparing this with the duplicidentate arrangement of the upper incisors of the rabbit, reaches the startling conclusion that it would not be surprising if in an earlier stage of his evolution man might have once been a "Duplicidentatus;" while Sera (1920), in order to accommodate his theory that all the teeth have been derived from molariform, many-cusped teeth, ignores the cynodont reptiles, which actually stand in or near the line of human evolution, and invents a queer hypothetical animal with a skull like *Oudenodon* but with a row of multicuspid molariform teeth all around the margin of the upper jaw! Small wonder it is that the

veteran anthropologist Sergi, perhaps disgusted with the multitude of mutually contradictory and fictitious human ancestors, and evidently misreading the facts of mammalian evolution, throws over (in his work "L'Origine e l'Evoluzione della Vita") the whole idea; and in a letter to the writer claims "that there is not a transformation in evolution, as now is the general theory, but that the types of animals and plants have independent origin and there are no progenitors whatever."

Parallel, convergent and divergent evolution of the deciduous and permanent dentures; interaction of the two sets

It is becoming increasingly obvious that many characters of form and of position in both sets of teeth are predetermined by the topographic relations, relative size, degree of crowding, etc., of the germs of the teeth during development and replacement, as when the lateral upper incisor is overlapped by the central, or when one of the lower incisors is crowded out of the incisor arch. Such relations of the incisors to developmental conditions are now being investigated by Dr. Milo Hellman with illuminating results which will be reported elsewhere.

The growth energy available for the jaws and teeth, especially in the higher races of man, has been restricted more or less as the relative size and dominance of the brain has increased. Not only have the dental germs decreased in size, but the two sets are so crowded together that some of the permanent teeth, notably the third molars, are greatly delayed in their eruption.

At least after the period of infancy and lactation the digestive tracts and foods of most young placental mammals are very similar to those of the adult. Hence, perhaps through natural selection, the deciduous teeth often resemble the adult teeth of the same animal in many important characters.

It is often assumed, through an unwarranted application of the "biogenetic law," that the deciduous are more primitive than the adult teeth. Sometimes it does happen that the deciduous teeth have not evolved as fast as have the corresponding teeth in the adult sets, perhaps because the deciduous set are relatively shortlived and do not have to provide for so long a period of attrition as do the permanent teeth. Moreover the young animal being small and its

strength less, the deciduous teeth will in general receive less severe impacts and stresses. On the other hand, the available space for the deciduous teeth being less, while the food is often just as resistant as in the adult, some of the deciduous teeth, especially the deciduous molars, must be of relatively large size and have a highly efficient crown pattern. Hence it happens that the crown pattern of the *last deciduous molars often converges in its evolution toward that of the last permanent molars*. Here we can see clearly that we are dealing with a convergence between differently numbered representatives of the two sets; and in many groups, including the whole catarrhine series, the posterior deciduous molars are fully molariform and very unlike the posterior true premolars which replace them. But an uncritical application of the biogenetic law would lead to the erroneous inference that the posterior premolars had been derived by degeneration from earlier adult teeth which resembled the posterior deciduous molars.

While the two sets of teeth parallel or converge toward each other in many respects, there are also many conditions that tend to bring about the characteristic differences between them, especially the following well-known factors:

(1) The development of the first set must be started in the intrauterine period, when available space is at a high premium. Hence the first ones to erupt must be as small as practicable.

(2) The deciduous teeth must draw their own nourishment in the jaws of the animal, which at first is of small size, requiring less food, but increases rapidly in bulk and in food requirements according to a variously accelerated rate. The developing teeth, in other words, must conform as far as possible to conditions arising from the excessive growth of the brain and from the ripening of the various endocrine or hormone-producing glands at different periods.

(3) Before eruption the tooth germs are drawing upon borrowed capital, but when they come into use each one is expected, so to speak to contribute more or less to the income by its service in cutting off and subdividing the food.

(4) But as the extent of their services at any given moment is limited by their cutting area, while the requirements are constantly increasing in some relation to the cube of the animal's height, there

would come a time when the deciduous set as a whole would not be large enough for the needs of the animal.

(5) It is not practicable to replace them all at once, hence the process is distributed over a long period.

(6) The process of replacement must not interfere with, but must even assist in maintaining, effective occlusal relations at all periods.

(7) Owing to the relatively small size and strength of the very young and to the undeveloped condition of the sex glands, the pugnacity of very young animals is notably less than that of adults and where the young are shielded from harm, as in man, there is less need for tusk-like canines.

(8) On the other hand, the food of the young being often as tough and resistant as that of the adult, it has proved advantageous in man to have the first permanent incisors and first molars come into use at an early period.

Although the interaction of these and of many similar factors (which will occur to every observer) is too complex to be considered here at any length, it is obvious that these factors and their interaction are responsible for many of the following classes of facts:

(1) Differences between the deciduous teeth and the teeth that replace them (e.g., divergence of roots of deciduous teeth to accommodate replacing teeth, resorption of roots of deciduous teeth as the period of replacement approaches).

(2) Elaborately adjusted relations of size and of time of replacement between deciduous teeth and their successors and neighbors; resulting malocclusions when such normal size and time relations are disturbed.

(3) Delayed eruption (as compared with prehuman stages) of permanent canines, anterior premolars and third molars.

(4) Ontogenetic changes in form of the palatal arch as a whole and in its several parts, resulting from successive replacement of deciduous teeth.

(5) Ontogenetic changes in the chin, made possible by the replacement of the deciduous incisors and canines and by the moving up of the permanent incisors out of their place of origin immediately behind the chin.

The superior and inferior dental arches

Osborn (1902) showed that in many phyla of mammals there is a relatively high degree of correlation between the breadth of the braincase and that of the palatal arch, and Angle (1905) and R. C. Osburn (1910) have shown that, at least in many cases, a wide, short skull will bear a wide palatal arch and *vice versa*. But Sullivan (1918) showed that "the principle of dolichocephaly and brachycephaly, in itself, is not sufficient to explain the form of the alveolar arch;" and that in many human races and individuals, and in various species of other primates, there are striking exceptions in which a wide palate is associated with a narrow braincase and *vice versa*. Thus in man the Eskimo have a very wide palate and a very long braincase, while among other primates "*Hapale* shows the longest braincase and the shortest alveolar arch . . . . *Macacus*, *Gorilla* and *Orang* show a relatively short, wide braincase and a very elongated palate."

These and similar exceptions to the "principle of dolichocephaly and brachycephaly" are obviously due to the fact that the palate and the braincase are subject to a complex of similar and different forces both in ontogeny and in phylogeny.

Chief among the conditions that tend toward the association of width of palate with width of braincase is this: That an increase in width in the lower part of the brain will often tend to cause an increase in width of the intercondylar diameter of the skull, since the temporal bones and the glenoid will be displaced laterally. This will tend to widen the distance between the condyles of the mandible. This in turn will leave room for a transverse expansion of the tongue. It is indeed probable that in man both the palatal arch and the lower jaw are, so to speak, moulded around the greatly enlarged tongue which appears very early in development as the "tuberculum impar;" and it is evident that the tongue of man as compared with that of anthropoids, tends to be short, thick and wide. Again a reduction in size of the incisors, canines and premolars will tend to shorten the palate at the front end, while the reverse will lengthen it. Increasing verticality of the incisors will again tend to shorten it. These contrasts are well brought out in comparing prognathous, macrodont and

dolichocephalic skulls with orthognathous, microdont, brachycephalic types.

On the other hand, a wide palate may become associated with a narrow cranium in opposite ways, as follows:

(1) By a secondary narrowing of the braincase, as probably in the Eskimo, which may have been derived from mongoloids with a wide palate and short skull.

(2) By a direct shortening of the palate, due to the loss of one or more molars, as in *Hapale*. Here the extreme antero-posterior diameter of the braincase has little if any relation to the form of the palate.

Conversely a long palate may be found with a short, wide cranium in the following ways:

(1) Through a marked increase in antero-posterior diameter of the molars, as in the gorilla.

(2) Through marked increase in length of the whole muzzle, as in baboons.

(3) Through an increase in size and procumbency of the incisors as in many orangs.

Sullivan (1918, p. 9) also showed that in the races of man there is a more constant relation between width of face and width of palate. In other words, where the cheek bones project laterally, as in mongolians, the palate is usually wide.

Hellman (1918, 1919) has shown that in the anthropoid apes the upper and lower dental arches of the same animal may differ widely from each other and that this is also true, perhaps even in greater degree, in man.

It has been noted above (p. 170) that the form of the front part of the palatal arch is naturally influenced by the form, size and position of the various teeth, and that when we find wide or procumbent centrals coincident with small vertical canines and bicuspids, the upper incisor arch may be more or less convergent or Λ-shaped. (*fig. 340*). In the Mousterian youth, as noted above (p. 148), the small left lower deciduous canine is in place and consequently the left half of the arch is more convergent than is the right, in which the large permanent canine is in place.

Hellman observes that an edge-to-edge bite often conditions a regularly arranged lower incisor arch, while the overbite relation favors a crowding and overlapping of the lower incisors.

Individual differences in the details of normal occlusion

I have often observed that in mammals having an orthodont or vertical jaw movement the blades of the upper and lower teeth are closely adjusted to each other, and that this permits but little variability except in non-articulating parts of the teeth. On the other hand, in mammals having varied lateral and rotary movements of the jaw, as in certain Eocene lemuroids, as long as certain main adjustments are conserved (such as the fitting of the hypoconids of the lower into the central fossæ of the upper molars) there is opportunity for many individual differences in detail, as to degree of development of certain parts (such as the mesostyle) and in the paths of the mandible at different times. The low-crowned teeth of man, with rotary and oblique movements of the mandible, afford opportunity for considerable individual differences. Hellman (1919) has shown that the classic concept of normal occlusion is far too rigid and restricted, since it has left out of account the wide range of variability in the details of occlusion.

The occlusal relations of the upper and lower cheek teeth are illustrated in *figs. 315, 316* and *319–323.*

Origin of the chin

Various authors have advanced different views of the mode of origin of the bony chin. Perhaps the most probable explanation is that upheld by Hrdlička (1911) in the following passage:

"As to the chin, the inferior part of the lower jaw is quite passive, and man, especially the white man, has a pronounced chin to his jaw today not because of a growth of chin but mainly because of reduction of the dental arch, which was not attended to an equal degree by reduction of the parts underneath. The inferior or chin portion of the lower jaw has not degenerated, or degenerated but little; it is functional as a supporting part and remained in length, more than the alveolar arch, as it was in older times. The alveolar arch, diminishing gradually further and further, left the lower anterior part of the horizontal rami, formerly more posterior than the foremost part of the arch, protruding, and this protrusion became shaped into a chin. Somewhat similar results are observable today in persons of different ages. In the old, where the alveolar arch has been still

more reduced through loss of teeth and absorption, there is as a direct result more prominence to the chin. The so-called lantern jaw of the aged is well known to all of you."

The shrinking of the dental arch in front and the increasing verticality of the incisors and canines are no doubt important factors in the production of a protruding bony chin. One reason for the fullness of the jaw in the chin region is the presence there, in the young, of the relatively large but as yet unerupted permanent incisors and canines. The long roots of these teeth when erupted also necessitate a deep chin. Robinson (1913) emphasizes the importance of the muscles of the tongue as a factor in the evolution of the chin, since these muscles require a firm base of attachment furnished by the lingual side of the jaw bone behind the chin.

The premolars and molars

The range in size of the premolars in *Homo sapiens* shows considerable variation from the very large premolars of the Talgai youth to the small premolars prevalent in the higher races. The pattern of the premolar crowns varies from the relatively primitive condition shown in certain natives of New Britain (cf. Adloff, 1908) to the reduced or simplified premolar bicuspid patterns of higher races (see pp. 149–150 and *figs. 324-329*).

The molars of modern men show a conspicuous variation in the number of cusps, which has been studied by many authors. In 1888 Cope published an extended and well-illustrated account of his observations on the molar-cusp formula of many races, which varies from $\frac{4-4-4}{5-5-5}$ in primitive types to $\frac{4-3-3}{4-4-4}$. Zuckerkandl (quoted by Adloff), Adloff (1908, p. 58), Sullivan (1920) and others have also contributed to the subject, Adloff recording also the number of cusps in the neanderthaloids.

More or less in association with the reduction in number of cusps, the upper molars, especially the second, gradually lose their quadrate form and become secondarily "tritubercular." Meanwhile the lower molars, with the loss of the hypoconulid, lose nearly all traces of the *Dryopithecus* pattern, which is completely replaced by the +-shaped pattern. These degenerative changes in the pattern of the crowns

are also accompanied by reduction in size, and Keith (1913) distinguishes "supra-plenal," "plenal" and "sub-plenal" stages.

As the third upper and lower molars are also greatly delayed in eruption, especially among higher races, they are evidently decadent teeth which may eventually be entirely lost. The first upper and lower molars are usually more conservative, both in the crown patterns and in size, than the second and still more than the third molars.

Another character of the molars which has been studied by many authors is the Carabelli cusp, or tuberculum anomalum. Cope (1888), Schwalbe, Adloff (1908) and others have recognized that this cusp has been derived from the basal cingulum. Jeanselme(1917) has refuted the suggestion that the cusp is associated with hereditary syphilis. He frequently found it among negroid and Asiatic races, among the Malagasy, or natives of Madagascar, among the Indians of the New World and among the inhabitants of the islands of the Pacific Ocean (Micronesians, Indonesians, Polynesians). Its occurrence among the Neanderthal race is discussed above (p. 152).

Racial characters of the dentition

Apart from a few striking cases, presently to be noted, racial characters in the teeth are at most not very conspicuous. The matter has been ably summarized by Hrdlička (1911) in the following passages:

"I want now to say a few words about the *differences of the denture and dentition in various races.* And it may be stated right from the start that should we eliminate the white race from comparison such differences would be small. With the exception of the size of the teeth, which is greater in some of the primitive peoples than in the civilized whites, and which also differs from one group to another among these races themselves according to their habits, there is but little variation. The type of human denture can be said to be today, with a few exceptions, radically everywhere the same. About the greatest of these exceptions concerns the form of the upper permanent incisors, which in one respect are radically different in the Indians from what they are in the whites, negroes, and at least some other races. The upper and particularly median upper permanent incisors of the Indian are, as you will observe in the specimens brought here for your examination, peculiarly and pronouncedly concave on the buccal surface. I call these teeth shovel-shaped. The condition is seen with

special clearness before the teeth have suffered any wear. I have called attention to this feature in a number of my publications. It is due to an extraordinary development of the lateral borders of the ventral surface of the crown. Sometimes these borders are so developed that they appear as if folded over the sides of the buccal surface of the tooth. They converge upwards, and at the points of convergence there is often seen a more or less rudimentary cusp. At the same time the dorsal surface of the crown is frequently more convex from above downwards than in the whites. This form of an incisor is found only seldom in the white, and, on the other hand, is but very seldom wanting in the Indian. Generally all the four upper incisors will be thus marked, but occasionally the condition is limited to the median incisors.

"Other racial differences in the teeth concern the cusps, roots, etc. They have in part been already mentioned in other connections. The white man shows more often a reduction in number of the cusps on the second and third molar than the negro and some other of the primitive races, and more frequently congenital absences of teeth, especially of the third molar. The root and crown of the third molar, and also the roots of the other teeth, are often more reduced in the whites. Finally, irregularities in position and the occurrence of decay are also most common in the white man.

"As to racial differences in dentition, i.e., the eruption of the teeth, our knowledge is as yet very defective. However, the white and the Indian have been investigated in this respect. I shall read a few lines based on my own studies of a large series of pure Indian children free from mixture, and you will see how insignificant, with perhaps one exception, the differences in the process of the eruption of the teeth are between the Whites and the Indians, two branches of humanity that are so far separated, or seem to be.

"The conditions found as a result of the investigation of 960 Apache and Pima children were as follows: All the teeth of the *first dentition* appear in the same order in the Indian children as in the white. As to time, the temporary incisors erupt on the average at about the same age in the two races; the appearance of the first temporary molars and the canines seems to be somewhat belated in the Indian; the eruption of the posterior temporary molars and the completion of the first dentition are accomplished earlier in the Indian than in the Caucasian.

"As to the permanent teeth, the incisors and bicuspids appear at nearly the same period of growth, as indicated by the height of the body in both races; the canines erupt possibly a little earlier in the Indians; the second molars appear decidedly earlier in the Indians than in whites; and the appearance

of the last molars is also probably on the average somewhat earlier than in whites. The earlier eruption of the second and also the third permanent molars, with probably that of the permanent canine, are, in the speaker's opinion, signs of a somewhat less advanced evolution, as explained before, of the teeth in the Indian than of those in the white people.

"Exactly what the conditions regarding dentition may be in other primitive races we do not know, but there are signs that they are in the main as in the Indian. The lack of pronounced racial differences in teeth or dentition indicates strongly a unity of origin of mankind."

Concerning the "shovel-shaped" incisors, Hrdlička (1920) has recently published the results of his intensive and widely extended observations. He found these characters to be frequently present in members of the yellow-brown races, less frequently among negroes and very rarely among whites.

The racial characters of the labial surface of the incisors have been investigated by Azoulay and Regnault (1893) and by Leon Williams (1914). The first two authors measured the difference between the length of the lower border of the central upper incisor and the length of a wire placed parallel to its upper border. They give the following table:

RACES	NUMBER OF SPECIMENS	DIFFERENCE
Apes (chimpanzees and gorillas, male and female)	5	3.04
Various negroes	41	2.39
New Caledonians, and New Hebrides	13	2.19
Australians	10	2.00
Polynesians	14	2.01
Annamese and Chinese	13	1.78
Europeans	18	1.61
Hindoos, Bengalis	7	1.27

From this they conclude that the inferior races (negroes, Papuans) have incisors which approach those of apes (in being wide at the bottom and narrow at the top.) The "yellows," the Europeans and the Hindus, on the contrary, have teeth with parallel borders.

Leon Williams (1914), on the contrary, although expecting to find racial differences in the form of the incisors, found his three types A, B, C, in all the races of men and of anthropoid apes. However it seems possible that if the subject could be studied statistically one

or the other type would be found more prevalent in the lower types of dentures.

One of the most conspicuous of dental racial characters is seen in the second upper molar of the Eskimo. Cope (1888) and Wortman observed that in these people the second upper molar loses its hypocone, and the remaining lingual cusp (protocone) becomes narrower, so that the tooth assumes a pseudo-tritubercular appearance.

As an aid to the study of racial differences in the dentition I have complied the appended conspectus of the species and chief races of the Hominidæ, after a critical study of the best modern authorities, especially Deniker (1915) and Haddon. But on account of the almost unlimited migration, mixture and local differentiation of races, it is extremely difficult in many cases to recognize the component elements of races, to distinguish convergent and independent resemblances from genuine marks of kinship, and finally to express the relationships in a linear system of classification. In spite of these difficulties the study of racial characters of the dentition and dental arches may yet assist in the solution of such questions as the following:

(1) Is the Caucasian race a natural group, or have the Mediterraneans, the Nordics, Alpines, etc., independently acquired pale skins? So far as the dentition indicates they seem to be closely related, all having "high" types of incisors, premolars and molars.

(2) Are the Mongolians and Alpines divergent derivatives of a single stock or do they merely parallel each other in certain characters?

(3) Were the neanderthaloids an entirely distinct race, or did some neanderthaloids somewhere give rise to *Homo sapiens?*

An understanding of the relationships of races and a correct evaluation of the racial characters of the dentition may be facilitated if we distinguish carefully between low or primitive and high or specialized characters. In general "low" characters include the following: The skin is dark, often very dark; it is uncertain whether the curly or the woolly form of hair is most primitive; the forehead is low, retreating, supraciliary ridges prominent, extending across the eyes, nose deeply notched at base, low and very wide below; face short, lower lip probably thick, but not excessively everted, upper lip thin; eyes small, deeply sunk, orbits with angulate corners; cheek bones moderately high; skull dolichocephalic, with prominent parietal eminences; an

edge-to-edge bite, crowns of incisors nearly vertical but roots of incisors directed backward; incisors often with rim-and-hollow; prognathous; palate Ω-shaped; chin not prominent; jaw massive, with wide ascending ramus; dentition macrodont, molar cusp formula $\frac{4-4-4}{5-5-5}$; m^3 and m_3 erupting relatively early and of large size; Carabelli's cusp frequently present on m^1, m^2; upper molars (m^1, m^2) of rhomboid form; *Dryopithecus* molar patterns more or less retained in lower molars; traces of *Dryopithecus* premolar patterns in the bicuspids.

"High" characters, on the contrary, include the following: The skin is light; hair straight or wavy; forehead steep, broad, no supraciliary ridges; face "long," nose long, delicate, narrow; lips not much everted; eyes large, orbits with rounded corners; cheek bones not high, skull brachycephalic or secondarily (?) dolichocephalic. Overbite of upper incisors; rim-and-hollow form of incisors rare; orthognathous; palate paraboloid to hyperboloid; chin prominent; jaw delicate; dentition microdont, molar cusp formula $\frac{4-3-3}{4-4-4}$; m^3 and m_3 erupting very late, often suppressed; Carabelli cusp not common; second upper molars with rounded three-cusped crown; lower molars with +-shaped pattern; bicuspid patterns of conventional type.

III. CONSPECTUS OF THE SPECIES AND CHIEF RACES OF THE HOMINIDAE

Pithecanthropus

Pithecanthropus erectus. ? Lower Pleistocene, Java. Skull-top almost gibbon-like; referred m^2, m^3 very large, with divergent roots. Femur man-like, indicating erect gait. (See Part IV, p. 688.) Probably standing near the base of the human stem. (See p. 215, below.)

Palæanthropus

Homo (*Palæanthropus*) *heidelbergensis.* Middle Pleistocene, Germany. Mandible of great size, with no bony chin; ascending ramus very wide. Dentition distinctly human, allied to Neanderthal type. (See pp. 125–139.)

Extremely ancient and primitive. Probably ancestral to the Neanderthal race and at least near to the ancestors of the higher races.

Homo (*Palæanthropus*) *neanderthalensis.* Uppermost Pleistocene (Mousterian) of Europe. Skull very large, with very low retreating forehead and great supraorbital tori; skull wide posteriorly. Jaw stout, with retreating chin, dentition "taurodont." Palatal arch horse-shoe-shaped, wide. Stature short. (See pp. 140–156.)

The extreme taurodont condition of certain Neandethaloids is regarded as a specialization which carries this species off the line leading to higher races; but the condition was much less pronounced in certain specimens and the crowns of all the teeth in the Mousterian youth (see p. 142) are extremely primitive, retaining many simian features that are lost in later races.

Eoanthropus (?Homo)

Homo (*Eoanthropus*) *dawsoni.* Pleistocene, or possibly Upper Pliocene, Piltdown, England. Skull very large, with forehead steep and very little if any projection of infraorbital tori. Cranial walls extremely thick. Temporal region and other parts resembling Aurignacian skull (Ramström). If lower jaw be correctly associated, it and the dentition were extraordinarily chimpanzee-like. (See Part IV, p. 680.)

Relationship of skull with *Homo* turns largely on the moot question of association of the mandible with the skull.

Homo sapiens

A. CRÔ-MAGNONS AND OTHER DOLICHOCEPHALIC UPPER PALÆOLITHIC RACES

(1) *Homo sapiens Galley Hill.* England. Skull very dolicho. Jaw with well-formed chin. Lower molars very slightly taurodont. Lower molar cusp-formula: 5, 5, 5; transverse diameter of m_2 slightly less than antero-posterior diameter, a primitive character (Keith, 1913).

(2) *Homo sapiens Brünn-Předmost.* Upper Palæolithic (Post-Glacial), Moravia. Skull dolicho., forehead retreating, supraorbital tori prominent. Chin prominent. Orbits broad, low. First lower molar with five cusps and *Dryopithecus*-pattern. Second lower molar with reduced hypoconulid and incipient +-pattern (cf. Adloff, 1908, plate IX, *figs. 53, 54*).

A primitive race which may be allied with the Galley Hill type. (See Osborn, 1915, p. 336.)

(3) *Homo sapiens Crô-Magnonensis* (*aurignacensis*). Late Palæolithic (Aurignacian), Italy, France. Skull of high type, with reduced supraorbital tori. Dolicho., but with very broad, short, face and projecting cheek bones. Space between the eyes small, orbits wide, nose narrow,

aquiline. Jaw with complete chin. Palate narrow. Dental arches and dentition of relatively high type (Combe-Capelle skull). Stature very tall (Crô-Magnon) or very short (Obercassel).

The Crô-Magnon race is generally supposed to have become extinct or to have left but few traces in the modern populations of Europe, which for the most part are descended from the Neolithic and later invaders from Asia. The extinct race from Obercassel, in Bonn, differed from the Crô-Magnons chiefly in their very short stature.

B. NEGROIDS

(4) *Homo sapiens Grimaldiensis.* Upper Palæolithic, France. Skulls negroid, dolicho., but regarded by Keith as allied with Crô-Magnon. Dentition macrodont, of very low type. Upper dental arch narrow; prognathism marked. (*Figs. 331, 334.*) Probably an intrusive element in Europe (M. Grant).

(5) *Homo sapiens Boskop* (*H. capensis Broom*). Age and relationships uncertain. Boskop, South Africa. Compared with Crô-Magnon and Bantu skulls by Haughton.

(6) *Homo sapiens Bushman.* Bushmen, Hoi-koi, Hottentots (in part). Hair woolly ("peppercorn"). Skin yellowish. Skull dolicho., forehead steep. Nose very broad, cheek bones high. Orthognathous. Dentition (*fig. 265G*) occasionally with primitive features; lower molar crowns with wrinkled surface (cf. Adloff, 1908, plate V, *fig. 25*). Stature very short; steatopygous.

An ancient but specialized offshoot of the negroid stock; possibly represented in the Upper Palæolithic of France by ivory figurines of steatopygous women. The pictorial art of the Bushmen presents many curious points of resemblance to that of the Crô-Magnons (cf. Sollas, "Ancient Hunters").

(7) *Homo sapiens niger.* Sub-races: (a) Negrito, (b) Negro, (c) Melanesian. Hair woolly. Skin brownish or reddish-black to black. Skull usually dolicho., sometimes brachycephalic (Andamanese). Forehead often "bombed" in negroes. Nose broad. Prognathous. Lips often everted. Dentition macrodont (*figs. 283H, 265F*), especially in Melanesians, to microdont; primitive to specialized. Palatal arch Ω-shaped (many Melanesians) to Λ-shaped. Stature: short (Negrito), tall (some negroes), medium (Melanesians). Melanesians probably more primitive than negroes.

(8) *Homo sapiens tasmanianus.* Tasmanians (extinct). Hairy frizzy or woolly, skin chocolate-brown, skull subdolicho.; face broad, nose very broad and flat; prognathous; palatal arch sometimes Ω-shaped (*fig. 314*).

Differ from Australians and resemble Melanesians chiefly in their frizzy hair (*fig. 302*).

(9) *Homo sapiens australianus.* (a) Talgai (*figs. 337–338*), Queensland (?Pleistocene); (b) recent Australians (*figs. 308, 339*). (a) Skull of extremely low type, with very large palate and teeth, and marked prognathism. (b) Hair wavy or curly, beard abundant, skin chocolate-brown, skull dolicho., with prominent supraorbital tori; nose broad; prognathous. Dentition often macrodont and of low type. Palatal arch variable, often Ω-shaped. Molar-cusp formula often of "low" type $\left(\frac{4-4-3\frac{1}{2}}{5-5-5}\right)$. Stature moderate. Limbs slender.

The Australians are regarded by Deniker and Haddon as a "Pre-Dravidian" race, driven southward from southeastern India.

C. MELANOIDS OR MEDITERRANOIDS

(10) *Homo sapiens veddalis.* Veddas of Ceylon. Hair long, black, coarse, wavy or curly. Skin dark brown. Skull very dolicho. Face broad, orthognathous. Nose broad, depressed at root.

A very primitive race, possibly allied with the Dravidians.

(11) *Homo sapiens dravidicus.* Short, dark peoples of the Deccan. "Melano-Indians." Hair curly or wavy. Skin brownish black. Skull dolicho. Stature short. Deniker divides this group into two sub-races, as follows:

Sub-race a, platyrrhine: Nose broad, flat, face rounded.

Sub-race b, leptorrhine: Nose narrow, prominent, face elongate.

The Melano-Indians[11] are on the whole a primitive group. The platyrrhine, flat-faced, division affords a structural intermediate between the Australians below and the Indonesians above. The leptorrhine, long-faced, division, especially in the case of the Todas, show structural affinities on the one hand with the Ainus and on the other with the Indo-Afghans.

[11] There are a dozen or more "Hindoo" skulls (*fig. 340*) from southern India, in the American Museum of Natural History, which probably represent the dental characters of the Melano-Indians, possibly more or less mixed with other strains. The skull is dolicho- or mesocephalic. The palatal arch is more or less Λ-shaped or convergent in front; palate vaulted; the central incisors, often long-crowned, have the lingual face either flat or with one or more low vertical ridges, a few of them have the rim-and-hollow formation, but not in extreme form. The upper canines in males are rather large, with conical crowns. The molar-cusp formula varies from $\frac{4-4-4}{5-5-5}$ to $\frac{4-3-4}{4-4-4}$. Here then we have a mingling of "low" and "high" characters, in harmony with the supposed position of the Melano-Indians near the point of divergence of the Mediterranean and Indo-Afghan groups.

Fig. 333

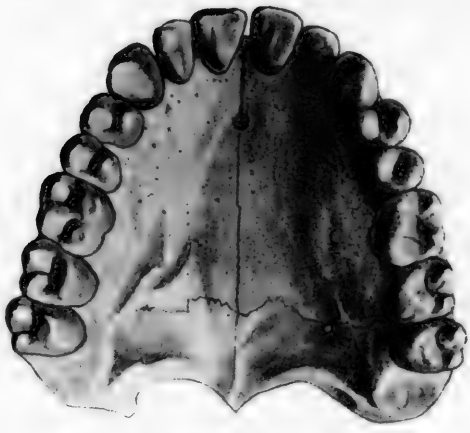


Fig. 332

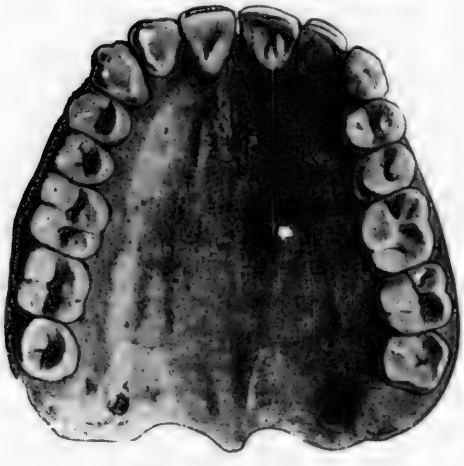
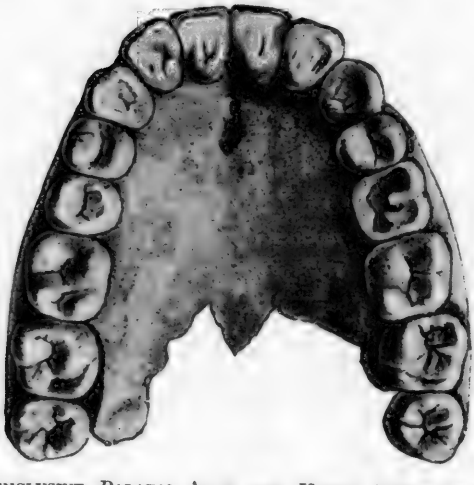


Fig. 331



Figs. 331–333, inclusive. Palatal Arch and Upper Teeth of Grimaldi, New Britain and Modern French Skulls. Modified from Verneau; After Gaudry

Fig. 336

Fig. 335

Fig. 334

Figs. 334–336, inclusive. Lower Dental Arch and Teeth of Same Series as in Figs. 330–333. Modified from Verneau; After Gaudry

FIG. 337. FOSSIL SKULL FROM TALGAI, QUEENSLAND, AUSTRALIA

Courtesy of S. A. Smith. Normal verticalis, and sagittal section of crushed skull

(12) *Homo sapiens indo-afghanus.* According to Deniker this race predominates in the northwest of India and includes Siks, Rajputs, some Hindus, Punjabi, Todas (in part); also among the Afghans. Hair wavy or straight, complexion light brown or tanned. Skull dolicho.; nose thin, prominent; stature high.

The Indo-Afghan race may have derived some of its "high" characters (tall stature, narrow nose, light color) by mixture with "Aryan" invaders, related to the Nordics. (Cf. Haddon, pp. 58, 59, 49; M. Grant, 1921.)

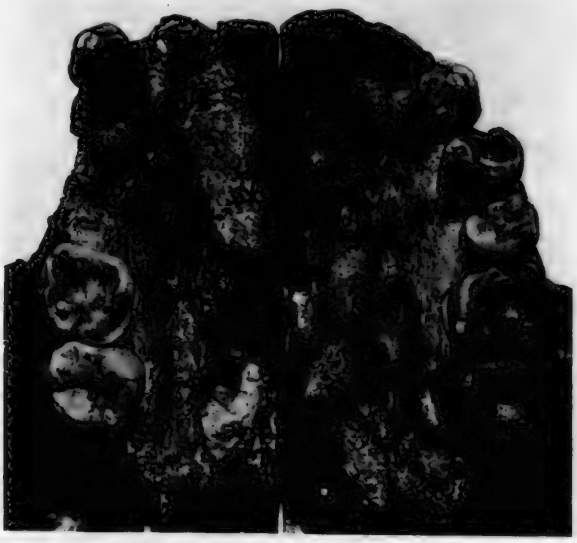


FIG. 338. PALATE OF TALGAI SKULL. × 1. AFTER S. A. SMITH

Deniker (1915, p. 289), in his "grouping of the human races according to their affinities," places the Indo-Afghan race next to the Arab-Berber group, which they resemble in many characters.

(13) *Homo sapiens ethiopicus.* Ethiopians (Kushito-Hamites) of northeast Africa, including ancient and modern Egyptians (in part), Beja, Galla, Somali, etc. Hair curly or frizzy. Skin reddish brown to chocolate-colored. Skull dolicho. Nose prominent, often long and narrow; face elongate, oval, not prognathous. Stature moderate to high. (Deniker, p. 438.)

The Ethiopians, although often having frizzy hair and very dark skins, differ from the negroid group in their "high" characters.

(14) *Homo sapiens mediterraneus.* "Mediterranean" group in part. Hair wavy, black; skin tawny-white (melanochroic), eyes dark. Skull usually dolicho.; nose narrow. Deniker divides this group as follows:

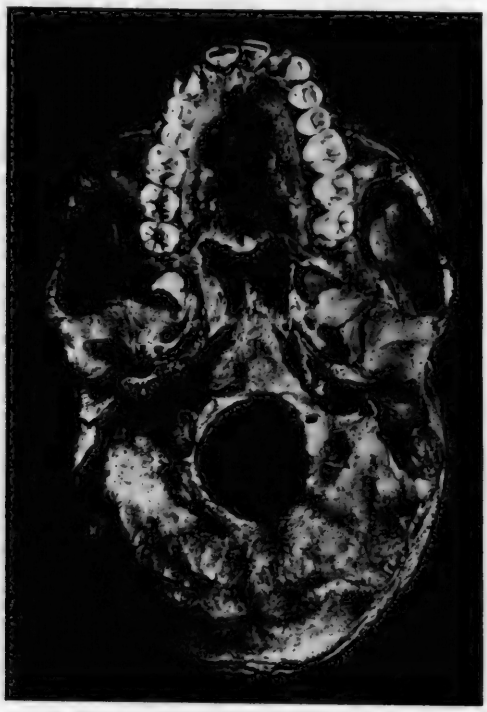


FIG. 339. SKULL OF AUSTRALIAN FEMALE

American Museum of Natural History, no. 3,280.

Sub-race a: *meditarraneus berber.* Berbers (Hamites) of northern Africa. Although there is a very great variety of types in this sub-race, Deniker (p. 432) gives the following as a "quite general characterization:" Nose straight or concave rather than aquiline; a transverse depression on the forehead above the glabella; face almost quadrangular. Skull, generally speaking, not so long as that of the Arab; occiput not so prominent; stature scarcely above the average. Often more or less "Arabised" in language and usages.

FIG. 340. SKULL AND MANDIBLE OF "HINDOO" FROM SOUTHERN INDIA
American Museum of Natural History, no. $\frac{9}{7}\frac{9}{7}\frac{9}{7}2$

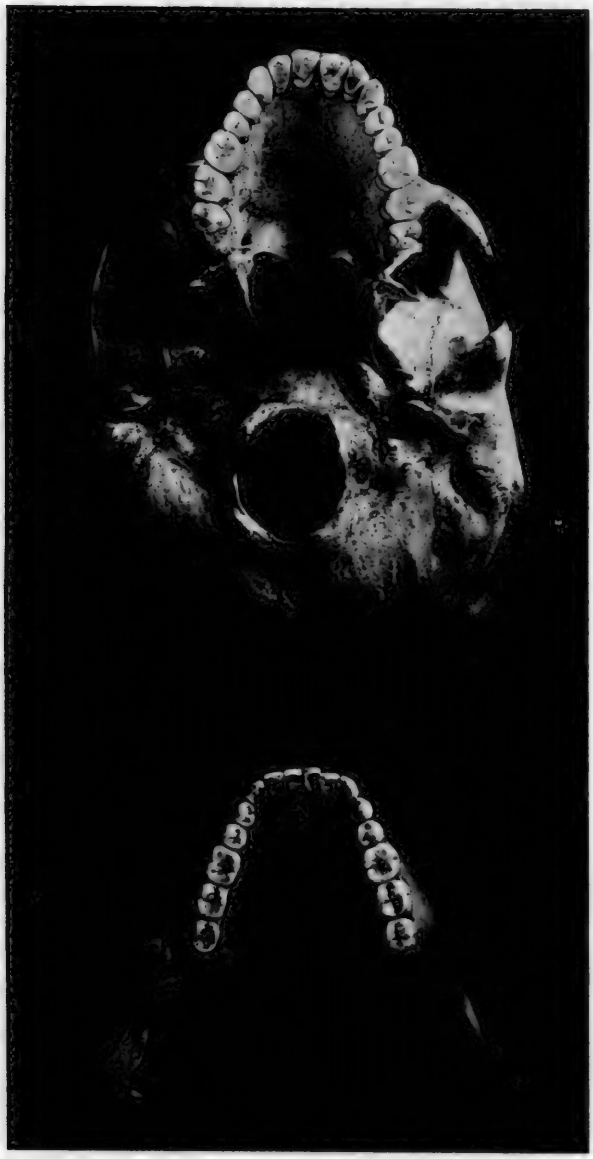


FIG. 341. SKULL AND MANDIBLE OF "BEDOUIN, FEMALE" FROM SYRIA
American Museum of Natural History, no. $\frac{99}{7125}$.

Sub-race b: *mediterraneus arabicus*. Arabs or Semites of Arabia, Mesopotamia, North Africa, etc. Nose aquiline, face elongate, oval. Skull typically dolicho., with prominent occiput. Stature tall, slim.

The true Bedouins of Arabia are more or less mixed with Assyroids, Turcoids, etc. (Deniker, p. 423). The skull shown in *fig. 341*, labelled "Bedouin, Syria," may not be a pure Arab type. It shows a thoroughly modernized dentition.

Sub-race c: *mediterraneus littoralis*. "Littoral or Atlanto-Mediterranean," Deniker. Mediterranean shore of northern Italy, southern France, Spain. Nose straight, fine; face oval, skull mesocephalic. Stature above the average (1 m. 66). Eyes and hair very dark. Status somewhat doubtful. May be a result of averaging dark, broad heads of the "Old Black Breed" type, with true Mediterraneans (Fleure and James, quoted by Madison Grant, 1921).

Sub-race d: *mediterraneus Ibero-insularis* (Deniker). Most Portuguese, Spanish, South Italians, Sicilians, Corsicans, "and the dolicho. . . . . neolithic inhabitants of Western Europe and the British Islands" (Haddon). Nose straight or turned up. Skull dolicho. Stature short. This sub-race differs widely from the other sub-races of this group, possibly as a result of crossing with Nordics and Alpines. It may be of Asiatic rather than North African origin.

The Mediterranean group may also be represented by some of the Upper Palæolithic skulls of Ofnet, on the Danube, northwest of Munich. Skull very dolicho., with narrow forehead and broad interparietal region. Face narrow. (Osborn, 1915, p. 480.)

D. AINU

(15) *Homo sapiens ainu*. Ainu of northern Japan. Hair wavy, very abundant as beard and on body. Skin light brown. Skull dolicho- or mesocephalic; supraorbital ridges prominent; face broad, orthognathus, with high cheek bones; *os japonicum* often present. Eyes large, horizontal; Mongolian fold usually absent. Nose concave, broad; stature short, thickset.

A race of uncertain relationships, resembling the Todas in their excessive hairiness, but certainly with a Mongoloid strain. Possibly related to the Proto-Nordics (M. Grant).

E. XANTHOIDS

(16) *Homo sapiens nordicus*. (*H. sapiens europæus* Linnæus.) The Nordic race, now centering in Sweden. Hair wavy, yellow, brown or red-

dish; eyes blue or grey; complexion reddish white; skull dolicho. Face elongate, nose prominent, straight. Orgnathous. Dentition "modern." Stature tall.

Sergi derived the Nordics from the "Eurafrican" or Mediterranean group of longheads, but Madison Grant (1915, pp. 170, 213) concludes that the Nordics "developed in eastern Germany, Poland and Russia, together with the grasslands which stretched from the Ukraine eastward into the steppes south of the Ural." Von Luschan (1911) also regards some of the Kurds and other longheaded peoples of western Asia, which have narrow nose and light eyes, as the descendants of primitive Nordics. In early times Nordics (Sacæ, etc.) penetrated far to the east, entering India and possibly even reaching China (cf. M. Grant, 1915). Some of the Galtchas of East Turkestan described by Ujfalvy (1887) present a remarkable mixture of apparent Nordic, Alpine and perhaps Indo-Afghan characters. They speak very primitive Aryan languages. Their "Nordic" characters (e.g., occasional blondness and blue eyes) may be due to ancient crossing with eastern offshoots of the Nordics. On the other hand, "the Galtcha skull measured by Topinard was said to present not only simple resemblances, but even an identity almost complete with the best characterized skulls of Savoyards (Alpine type)." (Topinard, quoted by Keane.) According to Keane (1900, pp. 553–556) the Galtchic-speaking tribes of the Hindu Kush, Kafirstan, Upper Indus, etc., include one group of brachycephalic Alpine type and another of the long-headed, blond Aryan type.

The more remote origin of the Nordics and their phyletic relationships with the Mediterraneans and the Alpines remain to be demonstrated.

The problem of the origin of the Nordics is bound up with the following questions, the solution of which may perhaps be approached not only through studies on the modern dentitions and skulls, but especially through a study of past migrations and racial contacts:

(a) In general is the "Caucasian race" a natural group, or have Nordics, Alpines, and Mediterraneans been derived from quite different stocks by convergence toward a "Caucasian" type?

(b) More in detail, are the Nordics more nearly allied with the Alpines, and is their dolichocephaly thus due to a secondary elongation of a hypsi-brachycephalic skull?

(c) Or are the Nordics derived from some relatively primitive dolichocephalic type such as von Luschan's Kurds, proto-Ainus, Tajiks, Galchas?

(d) Are the Mediterraneans of Europe derived from North Africa or from Asia?

(e) Are the Alpines, and with them the Armenians, derived from a primitive Central Asiatic Turco-Tatar-like group, and

(f) Are the latter related to the Ugrians and other Mongolians?

(g) Or are the Alpines derived from some ancient Galtcha-like race near to the stem of Nordics and Mediterraneans?

F. ALPINOIDS

(17) *Homo sapiens assyroideus.* Represented on the Assyrian monuments. Now much mixed with other races, but its traits seen among Hadjemi-Persians, Ayssores, some Armenians and some Jews. Hair wavy, or curly, skin tawny-white, skull brachycephalic. Nose in the form of a figure 6, thick at top, eyebrows united, lower lip thick. Possibly related to Indo-Afghan type (Deniker). Arabized Hittites (M. Grant).

(18) *Homo sapiens armenianus.* Hittites. Represented on the Hittite monuments. Now much mixed with other races, especially Armenians, Arabs, Turks, Greeks (von Luschan, 1911). Skull excessively high (hypicephalic), with flattened occiput (planoccipital); nose typically of great size, long, narrow and protruding far in front of chin. Skin tawny-white. Believed by von Luschan to have once been widely distributed in Western Asia and to be somehow connected with the origin of the "Alpine" races of Europe.

(19) *Homo sapiens adriaticus* (Dinaric). Coast of Northern Adriatic, especially in Bosnia, Dalmatia, Croatia, Tyrol, central France, etc. Skin dull white; hair brown. Skull very brachycephalic; face elongate. Stature tall. Deniker. (Probably related to no. 18 above.)

(20) *Homo sapiens alpinus* (Cevenole). "Western European." Abundant in southern Germany, Russia, the Balkans, central and northern Italy, central France. Skin dull white, hair dark brown, eyes hazel gray. Skull very brachycephalic, face round, nose often sharp. Stature short; palate often wide; dentition of "modern" type, not differing greatly from Nordic type.

Much mixed with Nordics in Germany, France, Belgium, Russia; with the Mediterraneans, in southern Italy and elsewhere. The "Eastern European" of Deniker has the round head of the Alpines combined with the fair skin, light yellow hair and blue or gray eyes of the Nordics and is often regarded as a cross between these two. In northern Russia and elsewhere the Eastern European is again crossed with Ugrians, Lapps, Turco-Tartars and other races of more recent Asiatic origin. Possibly the Furfooz-Grenelle race of the Late Palæolithic of Belgium and France may represent an early immigration of Alpines from Asia (Osborn). The Beaker-maker type of tall round heads, found in some of the Neolithic "round barrows" of England, and the Borreby type of Denmark, which have strong supraciliary ridges, may be allied to the Dinaric or Adriatic type (Madison Grant).

G. MONGOLOIDS

(21) *Homo sapiens Turco-Tatar.* Turkish race. Eastern Europe and central Asia. Best preserved in the "Turks of the Central group" (Deniker, p. 376), comprising among others the Kirghiz-Kazak of the plains between the Irtish and the Caspian, the Kara-Kirghiz of the Tianchan mountains, the Uzbegs and Sartes of Russian Turkestan, and the Tatars of the Volga; also the Astrakhan Tatars.

Hair straight to curly, moderately developed. Skin yellowish-white; skull extremely brachycephalic; face elongated, oval; eyes not Mongoloid (oblique), but often with the epicanthic fold. Cheek bones broad, lips thick. Nose straight, somewhat prominent; eyes not Mongolian. Stature above the average. A tendency to obesity.

In the eastern group profoundly modified by intermixtures with the Mongolian, Tungus, and Ugrian races, in the central group by crossing with Assyroid, Armenoid, Indo-Afghan, Arab and certain European races, chiefly Adriatic (Deniker). The Osmanli Turks of Asia Minor and Turkey are mixed with Armenoids and other races (von Luschan). The characters of the existing Turkish race are widely different from those of the typical Mongoloids, and suggest relationship with the Armenoid race, as well as with the Ugrian group of Mongoloids.

(22) *Homo sapiens mongoloideus.* Hair straight, skin pale yellowish, body smooth. Skull mostly brachycephalic. Face broad, typically orthognathous, with projecting cheek bones. Eyes usually oblique, with Mongoloid fold. Nose usually short, often concave. Upper incisors usually shovel-shaped. Palate wide. Stature mostly low. The following subdivision into sub-races is modified from Haddon and Deniker:

Sub-race a: *mongoloideus ugrianus.* Ugro-Finns, Yeniseans, Eastern Finns (in part). Peoples of western Siberia, especially Ostyaks, Tubas, Voguls, Samoyads; Votyaks and Cheremias of Russia. Extensively mixed with other races and represented in the Finns, Esthonians, Livonians, Bulgars, Magyars, etc. Hair straight, skin yellowish white. Skull "meso- or dolichocephalic" (Deniker), "brachycephalic" (Haddon). Nose straight or concave, cheek bones projecting. Stature short.

Sub-race b: *mongoloideus lapponicus.* Lapps of northern Scandinavia. Skin yellowish-white; hair straight, dark brown. Skull extremely brachycephalic. Face very broad, cheek bones prominent, orthognathous. Stature very short. Closely allied with the Ugrian race.

Sub-race c: *mongoloideus palæasiaticus.* East Siberians: Yukaghirs, Chukchis, Gilyaks (in part), etc. Hair long and lank, beard sparse. Color yellowish brown. Eyes oblique. Skull often meso-cephalic. Stature low.

Sub-race d: *mongoloideus Tungus-Manchu.* Skull meso- or slightly dolichocephalic, face rather elongated. Stature taller.

Sub-race e: *mongoloideus Koreanus.* Eyes with Mongoloid fold; beard long, thin. Skull brachycephalic; face long, narrow, often prognathous; nose narrow, aquiline. A modification of the Tungus type (Haddon, p. 17).

Sub-race f: *mongoloideus mongol.* Mongols proper.

(a) Western Mongols: Kalmuks of Astrakhan and the Caucasus.

(b) Eastern Mongols: Of Mongolia (Khalkhas; Buriat, in part).

Hair straight, black; skin pale yellowish or brownish; hair scant on body and face. Skull sub-brachycephalic. Cheek bones prominent; nose thin, straight; eyes Mongoloid.

Sub-race g: *mongoloideus australis.* Southern Mongols. "Most of the peoples of this group are considerably mixed with other races; they comprise the Tibetans, Himalayans, Chinese proper, and the bulk of the populations of further India and Indo-China. Those members who spread into the East Indian Archipelago are often called Oceanic Mongols, but a little better term is Proto-Malays; and it is from these the true Malay is derived." (Haddon, p. 18.)

Hair black and lank, with little hair on the face; skin color varies from yellowish on the north to olive and coppery brown on the south. Skull brachycephalic, often prognathous; nose short and broad; eyes often very oblique, with Mongolian fold. Stature generally short, often thick-set (Haddon).

(23) *Homo sapiens eskimo.* Labrador Eskimo, Greenland Eskimo, Aleuts (in part). Hair straight, skin brownish-yellow. Skull dolicho.; skull-top "scaphoid," with a compressed vault. Face round and flat, with projecting cheek bones. Eyes straight and black. Palate typically wide. Second upper molars relatively small, with only three cusps, the hypocone being lost. Lower jaw large. Stature short.

The Eskimo are often thought to be allied with the American Indians, but the connection is not clear; and they are regarded by Hrdlička (1911, p. 7) as a branch of the yellow or "Mongolic" race. They exhibit some characteristics of the Ugrian sub-race (short stature, dolichocephaly, shape of the eyes, etc.). (Deniker, p. 521.)

H. AMERINDS

(24) *Homo sapiens amerind.* American Indians. Hair typically straight, skin yellowish, brownish-yellow or brown. Skull often brachycephalic, but sometimes dolicho. Face has typically high, projecting cheek bones.

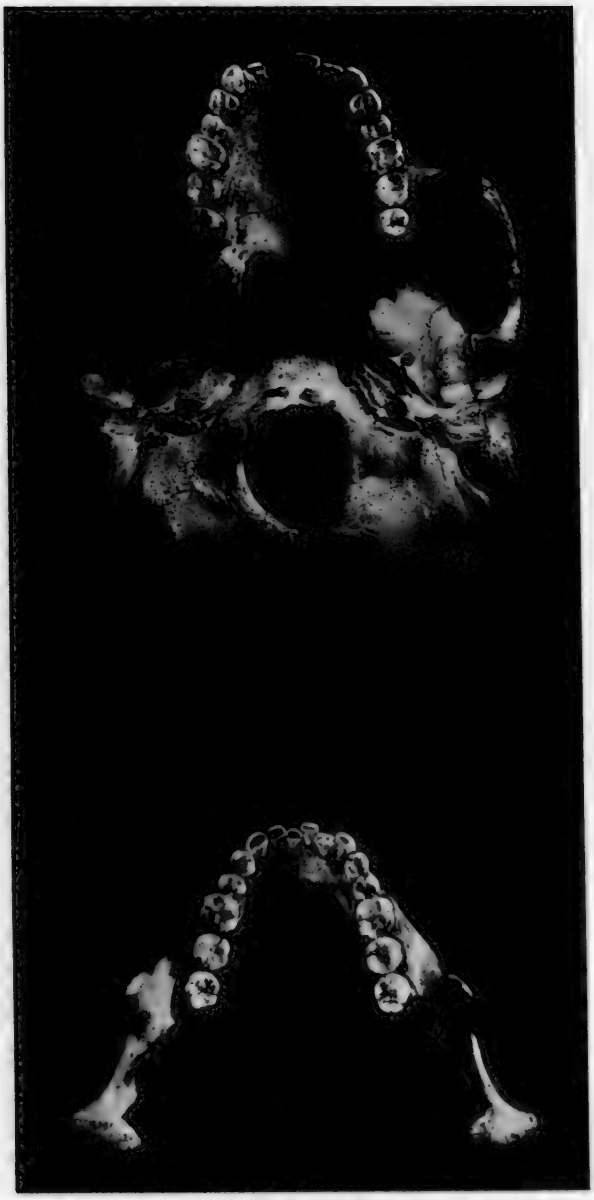


FIG. 342. SKULL AND MANDIBLE OF ESKIMO, FEMALE
American Museum of Natural History, no. $\frac{99}{1066}$

FIG. 343. SKULL AND MANDIBLE OF INDIAN FROM ILLINOIS
American Museum of Natural History, no. $\frac{99}{3651}$

Nose usually straight or aquiline. Eyes black. Palate often broad. Upper incisors shovel-shaped. Molars, often large, m_1 often with *Dryopithecus*-pattern (see Part IV, p. 708). Stature short, intermediate, sometimes tall.

Haddon, largely following Deniker, gives the following classification:

Sub-race a: *Palæo-Amerinds.* Botocudos and other South American tribes. Hair wavy or curly. Body smooth. Skull dolicho- or mesocephalic. Nose prominent, straight or concave. Stature short.

Sub-race b: *Patagonians.* Hair straight; nose straight. Skull brachycephalic; face square. Stature very tall.

Sub-race c: *Southern Amerinds.* Hair straight, skin yellow, body smooth, nose straight or concave, stature short. Skull meso- or brachycephalic.

Sub-race d: *Central Amerinds.* Central American tribes. Hair straight; skin brownish-yellow or brown. Skull brachycephalic; nose straight or aquiline. Stature short.

Sub-race e: *Northwestern Amerinds* of the Pacific slope. Hair straight, skin warm yellow. Skull brachycephalic; face usually rounded. Stature intermediate.

Sub-race f: *Northern Amerinds* of the Atlantic slope. Hair straight; skin warm yellow. Skull mesocephalic; face oval; nose straight or aquiline. Stature tall.

It is usually supposed that the Indians reached North America from the north; but some hold that the small yellow-skinned tribes of South America are connected wtih the Indonesians. The western spreading of the Indonesians and Polynesians, however, may be comparatively recent, while the Indian race has inhabited both North and South America for a very long period, probably since late glacial times. The extremely primitive character of many Indian molars and premolars suggests that the race has been derived from some very low group preceding the Crô-Magnons and allied to the stem of the Mongoloids.

I. OCEANIANS

(25) *Homo sapiens indonesianus.* Certain Indonesian tribes of Borneo, of the East Indian Archipelago and of the Philippines. Hair wavy, black; skin tawny, often light; body smooth; nose flat, sometimes concave; cheek bones often projecting. Skull dolicho. to brachycephalic.

More or less mixed with Proto-Malays, Hindus, Papuans, Melanesians, Polynesians, etc. Possibly derived from Dravidians, some of which approach the Indonesians in certain characters.

(26) *Homo sapiens polynesianus.* Hawaii to New Zealand. Hair wavy, long; skin yellowish; body smooth; skull brachy- or mesocephalic; nose prominent; face long, "elliptical." Stature tall.

"The Polynesians are a mixed people. Their original home was perhaps somewhere in Eastern India, whence shortly before our era, they migrated to the East Indian Archipelago, where we may speak of them as Indonesians. The Proto-Malays were about this time pressing down south from the mainland of Asia, and eventually a mixed population seems to have gone further east. . . . ." (Haddon, p. 21.) The latter spread into the islands of the Pacific.

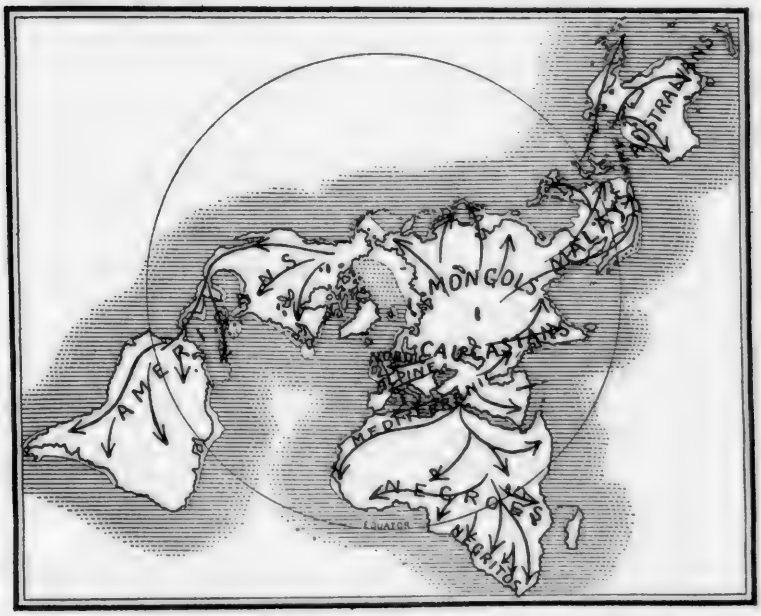


FIG. 344. DISPERSAL OF THE RACES OF MAN. AFTER MATTHEW

IV. SUMMARY AND CONCLUSIONS FOR PART V[12]

Darwin's conclusion was that "some ancient member of the anthropomorphous sub-group (of the Old World, or catarrhine series) gave birth to man." If this is incorrect then much of Parts IV and V of the present review is practically worthless, since all resemblances of

[12] The corresponding "summaries and conclusions" for the first four parts of this review were published successively on pages 166, 267, 424 and 690, of vol. ii (1920) of the JOURNAL OF DENTAL RESEARCH.—(Ed.)

the dentition between anthropoid apes would be based not on genetic kinship but on convergence, and the course of the supposed evolution of the dentition, as traced in this review, would be illusory rather than real.

It is illusory and unreal if Wood Jones instead of Darwin is right. Wood Jones (1918) holds that the existing *Tarsius* is the only living survivor, now highly specialized in certain features, of the very remote primate stock that gave rise to man; he approves Klaatsch's view that the monkeys and apes are best regarded as degenerate branches of the pro-human stock; he considers the apes more specialized than man, and suggests that many of the resemblances of apes to man are due to parallelism or convergence; he proclaims the "basal mammalian primitiveness" of the human skull and skeleton as well as many other human characters; finally he insists that palæontologists should acquaint themselves with the profound differences between human and anthropoid anatomy because these differences in his opinion far outweigh the resemblances in the bones and in the teeth; and he intimates that the skeletal parts are the only ones to which palæontologists have given due consideration.

The corner stone of Wood Jones' entire theory is the "basal mammalian primitiveness" of the human skull and skeleton. But as I have shown elsewhere (1920, *Pl. XXVII*), this assumption is flatly contradicted by the evidence of palæontology, taxonomy and comparative anatomy.

If we lay out on a long table a series of humeri, placing at the left those of various Paleocene and Eocene mammals, next the humeri of Eocene primates and at the right those of existing lemurs, platyrrhines, catarrhines, anthropoids, *Dryopithecus* and man in the order named, we shall see that the most primitive primate humeri, that is those most like the humeri of other Paleocene and Eocene mammals (which are known and universally admitted to be primitive), are not the humeri of man and of the anthropoids but the humeri of Eocene primates. We shall also see that there is a gradual change in form from the humeri of Eocene primates, which are most like those of quadrupedal Eocene mammals, to the humeri of the chimpanzee and of man, the latter two belonging to upright sitting animals that have real hands.

The "basal mammalian simplicity of the human skull" is equally an erroneous concept. For real "basal mammalian simplicity," or rather basal primate simplicity (which is a very different thing, although Wood Jones confuses the two), we must look not to man but to the Eocene primates, such as *Notharctus* (Part II), the skull of which approaches that of other Eocene placental mammals in very many characters not found in man.

As to the "wide differences" between human and anthropoid anatomy the answer is: first, that however numerous and great these differences may be, they have doubtless been acquired during the vast time since the human branch separated from the gorilla-chimpanzee stock; and secondly, that these differences are far outweighed in importance by the still more numerous and profound resemblances.

The latter has been widely recognized as a fact by all those who have made or are still making the most solid contributions to our knowledge of the comparative anatomy of the anthropoids: such as Deniker in his classic memoir (1886) on the anatomy of a fœtal gorilla; Keith, who for the past thirty years has continued his comprehensive and illuminating studies of the subject; Retzius, who described the remarkably human characters of the spermatozoa of the gorilla; Tilney, who testifies to the fundamentally human construction of the gorilla brain-stem; and many others.

It is an easy answer to almost any question concerning human evolution that "we must await palæontological evidence" rather than admit that the main outline of human evolution is already plain to all who can read the available record. In the case of man the palæontological part of the record is admittedly incomplete, and taken by itself would prove little. But when, from comparative anatomical evidence, we recognize the closeness of the relationship between man and the gorilla-chimpanzee group, the palæontological record is seen to be entirely in harmony with my conclusion that man is a late Tertiary offshoot of the *Dryopithecus-Sivapithecus* group, or at least of apes that closely resembled these genera in the construction of the jaw and dentition.

Two principal objections to this conclusion will doubtless be made by many palæontologists. The first is that the human grade of

organization was already attained as far back as the Middle or Lower Pleistocene and may at any time be expected to be found in the Pliocene, and that there is therefore not sufficient time to effect such a great transformation between the Pliocene and the Miocene. My answer to this is that it is a "fallacy of the undistributed middle," since it assumes that the rate of evolution for man is the same as that for horses and proboscideans, whereas the facts prove that *rates of evolution differ enormously in different phyla and at different times; that rates of evolution are as individual and specific as are the corresponding anatomical characters; that in the case of man all the evidence suggests that during late Tertiary times the rates of transformation were greatly accelerated, especially in the structure of the brain and of the feet.*

The second objection that will be raised against the conclusion cited above is that, with possibly two exceptions, all authors, from Darwin and Gaudry to Wood Jones, have recognized that *Dryopithecus* was already an ape and *therefore* that it cannot be in the human line. Smith Woodward (1914) on the other hand showed that, as regards the construction of the mandibular symphysis and the arrangement of the attachments for the tongue muscles, *Dryopithecus* appears to afford a starting point not only for the anthropoid but also for the human lines of specialization; while I, in earlier papers as well as in the present review, have shown that *Dryopithecus* as well as *Sivapithecus* give us an excellent starting point for the diverging specializations of the dentition of anthropoids and men. This can hardly be denied in so far as it applies to the upper and lower molars and premolars; but it will be objected that it is the presence of ape-like canines and ape-like lower premolars in *Dryopithecus* and *Sivapithecus* that rules them out of the line of human ascent. I on the other hand hold that the *conditions in which the tips of all the lower teeth are reduced to the same general level and the diastemata are closed up, is just as secondary in man as it is in Homalodotherium; that it is connected with the general reduction of the facial part of the skull and correlated with obvious changes in habits of feeding and of fighting; that there is no more "basal mammalian primitiveness" to be found in the human dentition than there is in the mandible or maxilla.*

The structural resemblances and differences between man and *Dryopithecus* with reference to characters of the jaws and dentition are summarised in *table 1*.

In respect of every one of these characters *Dryopithecus* is more primitive, more like other primates, than is typical man. And it should not be forgotten that the "Mousterian youth" and many Indian, Australian, Melanesean and other primitive dentitions retain intermediate or transitional features, which add their quota of evidence for the conclusion that the *Dryopithecus* group is structurally ancestral to man.

The wide differences between high human characters on the one hand and low, *Dryopithecus* characters on the other, are an expression of the difference in life habits between primitive apes and typical men. As Darwin and most anatomists have recognized, the direction of evolution rapidly changed and the old ape-like "heritage" was largely replaced by the new human "habitus." But many have forgotten the principle of "change of function;" they have in mind only the kind of predetermined and straightforward evolution that is illustrated in the palæontological history of the horses; they cite Dollo's "law of irreversibility of evolution" as a reason for doubting radical changes in the direction of human evolution, forgetting that great changes in function and in the direction of evolution were the very phenomena that Dollo used so brilliantly in formulating his law. Rightly perceiving that most groups are polyphyletic, many authors conceive those phyla as continuing backward indefinitely on parallel lines, so that the anthropologist Sergi has finally concluded that there never was any transformation, but that the various "types" of animals and plants were produced independently! Other authors, impressed by the great antiquity of many mammalian groups and by the extreme slowness of evolution in general, assume that the rate of evolution of man has been equally slow, so that they expect to find the human phylum already set off from other primates at a very early time, perhaps even in the Eocene.

Lartet, Gaudry, Dubois, Schlosser, Pilgrim, by their discoveries of fossil anthropoids, have prepared the way for the recognition of the truth of Darwin's conclusion that man was derived from "some ancient member of the anthropomorphous subgroup;" Schlosser (quoted

TABLE 1

Contrasts between Dryopithecus and man in the lower jaw and teeth

FEATURE	DRYOPITHECUS	MAN (TYPICAL)
Dental formula	$I\frac{2}{2}\ C\frac{1}{1}\ P\frac{3}{2}\ M\frac{3}{3}$	$I\frac{2}{2}\ C\frac{1}{1}\ P\frac{2}{2}\ M\frac{3=2}{3=2}$
Lower incisors	Slightly procumbent, not crowded	More erect, crowded, often more or less displaced
Diastema between lateral lower incisor and canine	Present	Closed
Diastema between lower canine and anterior premolar	Present	Closed
Crown of lateral lower incisors	Less expanded transversely, with remains of primitive tip	Expanded transversely and truncate at top
Lower canine	With pointed tip projecting considerably above level of premolars	With obtuse tip projecting but little above level of premolars
Axis of lower canine crown	Slightly inclined forward	Vertical
First lower bicuspid	Asymmetrical, with high tip and two roots	Symmetrical, with low tip and single root
Second lower bicuspid	Asymmetrical, with high tip, high trigonid and low talonid	Symmetrical, with low tip and reduced trigonid and talonid basins
First lower molar	Smaller than second lower molar, with five cusps and "*Dryopithecus*-pattern"	Longer than second molar, with five cusps and remnants of *Dryopithecus*-pattern
Second lower molar	With five cusps and *Dryopithecus*-pattern	With four cusps and + -shaped pattern
Third lower molar	The longest of the series, with five cusps and *Dryopithecus*-pattern	The shortest of the series, often with four cusps and modified *Dryopithecus*-pattern
Proportions of lower molars	Long and narrow	Short and broad

TABLE 1—*Continued*

FEATURE	DRYOPITHECUS	MAN (TYPICAL)
Intercondylar diameter	Relatively narrow	Very wide
Lower dental arch	With parallel sides	With converging sides
Space for tongue	Contracted, narrow	Expanded, wide
Symphysis	Relatively long and sloping	Very short and vertical
Bony chin	Retreating	Protruding
Ascending ramus	Very wide	Narrow

by Branco, 1898, p. 126) even regarded man as a derivative of those Upper Miocene anthropoids which gave rise to the gorilla, *Dryopithecus*, chimpanzee and orang, a view that very nearly anticipates my own.

Those who do not realize the cumulative and convincing character of the anatomical evidence for the close relationship of man with the gorilla-chimpanzee stock, and who look for ancestral Hominidæ in the early Tertiary, would probably fail to recognize a real human precursor as such, if it were found in the late Tertiary. We already have—to go back no further—*Parapithecus*, *Propliopithecus*, *Dryopithecus*, *Sivapithecus*, *Pithecanthropus*, *Homo* (*Palæanthropus*) *heidelbergensis*, *H. neanderthalensis* and many grades of *H. sapiens*. But many do not perceive that this forms an admirable structural sequence; they insist, with Boule, on "more fossils and many more fossils." Adloff and others reject Darwin's conclusion that man is an offshoot from "some ancient member of the anthropomorphous subgroup," but they have no difficulty in believing in the impossible[13] "concrescence theory" as applied to the origin of the human dentition.

The remaining conclusions for Part V will be found in the italicized sentences and headings on pages 109–178 above. They are also expressed graphically in *figs. 311–317*, and *319–329*.

[13] My reasons for calling the concrescence theory "impossible" are given above, on pages 159–163.

TABLE 2

Twenty-six structural stages in the ascent of

GEOLOGICAL AGE	STAGE NUMBER	STAGE	EXAMPLE, OR RELATED FORM
Recent	26	"High" human type (microdont)	*Homo sapiens*
Upper Pleistocene	25	"Low" human type	(*Homo "mousteriensis"*)[1]
Middle Pleistocene	24	Heidelberg race	*Homo heidelbergensis*
Lower Pleistocene		?	
Pliocene	23	Human precursor	*Pithecanthropus*
Miocene	22	Advanced pre-human anthropoid	*Sivapithecus* *Dryopithecus*
Oligocene	21	Primitive anthropoid	*Propliopithecus*
"	20	Supertarsioid	*Parapithecus*
Upper Eocene	19	Progressive tarsioid	(*Necrolemur*)[1]
Middle Eocene	18	Primitive pro-tarsioid	(*Omomys*)[1]
Lower Eocene	17	Primitive lemuroid	(*Pelycodus*)[1]
Paleocene	16	Insectivorous preprimate	(*Indrodon*)[1]
Cretaceous	15	Insectivorous preplacental	?
Jurassic	14	Pre-trituberculate mammal	*Amphitherium*
Triassic	13	Protodont mammal	*Dromotherium*
"	12	Advanced mammal-like reptile	*Ictidopsis*
Upper Permian	11	Intermediate mammal-like reptile	(*Cynosuchus*)[1]
Middle Permian	10	Early mammal-like reptile	(*Moschops*)[1]
Lower Permian	9	Primitive pelycosaurian reptile	(*Mycterosaurus*)[1]
"	8	Progressive cotylosaurian reptile	(*Captorhinus*)[1]
Upper Carboniferous	7	Primitive cotylosaurian reptile	? *Eosauravus*
Lower Carboniferous	6	Primitive amphibian	(*Loxomma*)[1]
Uppermost Devonian	5	Pro-tetrapod	*Thinopus*
Upper Devonian	4	Progressive crossopterygian fish	*Eusthenopteron*
Middle Devonian	3	Primitive crossopterygian fish	*Osteolepis*
?	2	Primitive fish with[2] gill-arch jaws	?
Upper Silurian	1	Primitive jawless fish	*Birkenia*[1]

[1] Not in direct line but more or less related thereto.

[2] *Cladoselache* of the Upper Devonian is a late survivor of this grade (*fig. 2*).

man and in the evolution of the human dentition

FIGURE NUMERAL	TAXONOMIC POSITION OF EXAMPLE			
	Class	Order	Suborder or section	Family
326,329	Mammalia	Primates	Catarrhinæ	Hominidæ
325,328	"	"	"	"
312,313	"	"	"	"
269	"	"	"	"
247	"	"	"	Simiidæ
248-255	"	"	"	Simiidæ
235	"	"	"	Parapithecidæ
215	"	"	Tarsioidea	Necrolemuridæ
136	"	"	Tarsioidea	Tarsiidæ
112	"	"	Lemuroidea	Notharctidæ
61	"	Menotyphla		Mixodectidæ
50	"	"Bunotheria"		
20	"	Trituberculata		Amphitheriidæ
15	"	Protodonta		Dromotheriidæ
9	Reptilia	Therapsida	Cynodontia	Cynognathidæ
	"	"	Gorgonopsia	Cynosuchidæ
Pl. 1	"	"	Dinocephalia	
347	"	Theromorpha	Poliosauria	
7	"	Cotylosauria	Captorhinomorpha	Captorhinidæ
	"	"		Sauravidæ
	Amphibia	Labyrinthodontia	Embolomeri	Loxommatidæ
	"	Protetrapoda		
4	Crossopterygii	Rhipidistia		Rhizodontidæ
	"	"		Osteolepidæ
1	Ostracodermi	Anaspida		Birkeniidæ

V. FINAL SUMMARY: TWENTY-SIX STRUCTURAL STAGES IN THE ASCENT OF MAN AND IN THE EVOLUTION OF THE HUMAN DENTITION.

DESCRIPTION OF STAGES 1–26

(1) *Primitive jawless fish.* Known relatives: Silurian anaspid ostracoderms (*Birkenia*, etc.).

Life zone: Freshwater streams, etc. Locomotor habitus: fish-like, but without pectoral and pelvic fins.

Food habits: probably sucking in minute organisms and organic matter.

Mouth and jaws suctorial.

Cartilaginous gill-arches not developed or not calcified.

Teeth, none.

Skin covered with denticles or flattened scutes.

(2) *Primitive gnathostome or jaw-bearing fish.* Known relatives: primitive Devonian sharks (*Climatius*, *Cladoselache*).

Life zone: freshwater streams, etc. Locomotor habitus: fish-like, with pectoral and pelvic fins of fin-lappet origin.

Jaws cartilaginous, calcified, derived from modified gill-arches and operated by modified gill-arch muscles.

Jaws, temporal region and whole body covered with skin bearing shagreen denticles.

Teeth derived from enlarged shagreen denticles, formed in many successive sets on skin covering the jaws.

(3) *Primitive crossopterygian.* Example: Devonian rhipidistian fish, *Osteolepis*.

Life zone: streams and swamps. Locomotor habitus: fish-like; pectoral and pelvic fins feather-shaped, with fleshy axis supported by cartilage rods.

Food habits predatory.

Gill-arch or primary jaws covered with ossified skin.

Jaws hyostylic, that is, supported by large hyomandibular.

Temporal region with continuous imperforate osseous dermal covering, including intertemporal, supratemporal, squamosal, quadrato-jugal and jugal.

Teeth sharply differentiated in form from scales, covering margins and inner sides of jaws and roof of mouth.

Marginal teeth pointed, with complexly infolded bases (labyrinthodont).

A series of derm bones covering opercular region and underside of throat.

(4) *Progressive crossopterygian.* Example: Upper Devonian rhipidistian fish, *Eusthenopteron.*

Life zone: streams and swamps.

Locomotor habitus: fish-like; pectoral fins fan-shaped, with abbreviate, thick, fleshy axis, supported by skeleton of pro-cheiropterygial type; pelvic fins of similar construction but narrower.

Food habits, jaws and skull, differing only in details from stage 3.

(5) *Protetrapod.* (Transitional from rhipidistian fish to primitive tetrapod.) Known only from a foot-print (*Thinopus antiquus* Marsh) from the Upper Devonian of Mauch Chunk, Pennsylvania.

(6) *Primitive amphibian.* Example: Lower Carboniferous stegocephalian, *Loxomma.*

Life zone: swamps. Locomotor habitus: primitive tetrapod type, with short, pentadactylate extremities.

Food habits predatory.

Jaws autostylic; upper jaw attached to base of cranium by basipterygoid processes; maxilla and dentary of moderate size.

Temporal region imperforate.

Opercular and gular elements lost; skull otherwise much as in stage 4.

Teeth much as in stage 4.

Palate in primitive forms much as in stage 4, in later Amphibia becoming widely open.

(7) *Primitive cotylosaurian reptile.* Example: Upper Carboniferous cotylosaur, *Eosauravus.*

Life zone: swamps. Locomotor habitus: primitive reptilian type.

Skull of *Eosauravus* not known, but skull of Lower Permian *Seymouria* will serve to represent this stage.

Otic notch (between tabular and squamosal bones well developed).

Temporal region imperforate, with separate intertemporal and supratemporal bones.

Jaws and teeth much as in stage 8.

(8) *Progressive cotylosaurian reptile.* Example: captorhinid cotylosaurs of the Permian.

Life zone: mostly dry land. Locomotor habitus: primitive reptilian type.

Food habits ?insectivorous, or perhaps feeding on crustaceans.

Jaws autostylic; maxilla and dentary much as in stage 7.

One of the coronoid and one of the splenial series lost.

Temporal region with imperforate bony covering; inter- and supratemporal bones lost. Otic notch lost.
Palate with Λ-shaped brace formed by pterygoids and quadrates.
Ectopterygoids forming downwardly projecting guards to prevent lateral displacement of the mandible.
Teeth losing the labyrinthodont structure, generally small and peg-like, becoming protothecodont.

(9) *Primitive pelycosaur (theromorph)*; Permian. Example: *Mycterosaurus*.
Life zone: dry land. Locomotor habitus: primitive lizard-like type.
Food habits insectivorous to carnivorous.
Skull more compressed, vertically deeper.
Jaws autostylic; maxilla and dentary becoming larger, dentary with a coronoid process.
Temporal region perforate, a temporal opening (the lateral temporal fenestra) lying below the postorbital-squamosal arch and above the jugal-squamosal arch.
Orbit bounded posteriorly by the postorbital-jugal bar; zygomatic arch (jugal-squamosal arch) homologous with that of mammals.
Palate braced as in stage 8.
Teeth conical, compressed, thecodont, often differentiated into incisors, canines and a postcanine series.

(10) *Early mammal-like reptile.* Example: *Moschops* (a specialized side branch).
Life zone: dry land. Locomotor habitus: somewhat as in pelycosaurs, but body well raised off the ground in walking.
Skull deep vertically.
Jaws autostylic.
Coronoid process of dentary meeting large surangular.
Temporal region much as in stage 9.
Teeth in two successional series, an outer and an inner one.
Front teeth specialized (in Dinocephalia), with high tip and very large basal swelling.

(11) *Intermediate mammal-like reptile.* Examples: primitive gorgonopsians of the Permian of South Africa.
Food habits predatory.
Ascending coronoid process of dentary becoming more prominent.
Teeth compressed recurved.
Pterygoids relatively weaker, quadrate reduced in size.
Temporal opening lying below postorbital-squamosal arch and above jugal-squamosal arch.

(12) *Advanced therapsid or theriodont.* Example: cynodont reptiles of the Triassic of South Africa.

Life zone: dry land. Locomotor apparatus: approaching monotreme mammalian type.

Food habits predatory.

Dentition differentiated into incisors, canines, premolars and molars.

Deciduous and permanent series as in mammals.

Cheek teeth compressed, incipiently triconodont, *or* with widely oval ridged upper molars articulating with subcircular lower molar crowns.

Each tooth supported by a single root.

Dentary the predominant element of the lower jaw; post-dentary elements (angular, surangular, articular and prearticular) becoming much reduced in size.

Quadrate small, its dorsal process received into a deep pocket in the squamosal.

Ascending ramus or coronoid process of dentary of very large size, the whole dentary bone approaching in form the mammalian mandible, but the mandibular condyle not yet developed.

Temporal region essentially mammal-like, with mammalian temporal fossæ; zygomatic arch formed by squamosal and jugal and postorbital.

Postglenoid and post-tympanic processes of squamosal developed.

Maxilla vertically deepened, in broad contact above with nasals.

A secondary palate, of submammalian type.

Pterygoids weakened posteriorly and barely reaching the quadrates.

(13) *Primitive mammalian stage.* Examples: *Dromotherium, Microconodon;* Upper Triassic, North America.

Food habits insectivorous.

Skull unknown, but probably retaining many characters from stage 12.

Lower jaw with small condylar process, implying the establishment of a secondary articulation between the squamosal and the dentary; otherwise ascending ramus of dentary much as in stage 12. Post-dentary elements probably reduced.

(In earlier stages the quadrate and articular bones were probably connected more or less directly with the tympanic membrane, as they are in recent reptiles. This condition persists in mammals where the quadrate has given rise to the incus and the articular to the malleus.)

Teeth differentiated into incisors, canines, premolars and molars.

Molar crowns compressed, protodont, with high central cusp and small anterior and posterior cusps.

Division of roots into anterior and posterior moieties more or less completely effected.

(14) *Pre-tritubercular stage.* Example: *Amphitherium*, of the order Trituberculata, Lower Jurassic, England.

Food habits insectivorous.

Skull not known, but probably without postorbital bone; with an elongate facial portion slightly deflected upon the low braincase.

Mandible with well defined pedunculate condyle and distinct angular process, the latter not inflected; inclination of coronoid process to body of dentary steeper; coronoid process wide, recurved above; condyle slightly above level of cheek teeth; mandible deeply grooved on inner side for reduced Meckelian cartilage and inferior dental nerve and vessels.

Dental formula: $I\frac{4}{4}$ $C\frac{1}{1}$ $P\frac{5}{5}$ $M\frac{6}{6}$.

Cheek teeth supported by anterior and posterior roots; premolars with simple, compressed, conical crowns and incipient talonids; molars with well defined trigonid and small talonids on inner surface of crown; protoconids asymmetrical, the metaconids directly medial to the protoconids.

Upper molars of *Amphitherium* not known, but, from evidence afforded by later trituberculates, they must have been triangular in form, separated by triangular interdental spaces; apex of each molar homologous with that of the premolars, as shown in *Peralestes* and *Dryolestes* of the Upper Jurassic; the primary apex, together with the outer border of the crown, forming the primary trigon.

(15) *Hypothetical stage.* Undiscovered ancestral insectivorous placentals ("Bunotheria") of the Cretaceous period.

Food habits insectivorous.

Dental formula: $I\frac{3}{3}$ $C\frac{1}{1}$ $P\frac{4}{4}$ $M\frac{3}{3}$.

Premolars retaining the primary trigon, but posterior upper premolars with small internal spur, the serial homologue of the future protocones.

Upper molars triangular, the apex of the primary trigon beginning to divide into two cusps, the para- and metacones. Lower internal spurs from the basal cingulum foreshadowing the future protocones.

Lower molars with high trigonids fitting into interdental spaces, and small talonids, narrow transversely, and bearing entoconid only.

The zalambdodont insectivore *Palæoryctes* of the Paleocene represents a structural survivor of this hypothetical ancestral group, which, in turn, may have been derived from the lower Jurassic trituberculates, especially *Amphitherium*, by the reduction in number of the molars from six to three.

(16) *Insectivorous pre-primate.* Possibly represented by *Indrodon* of the Paleocene. *Nothodectes* is a side branch of this group, with specialized front teeth.

This pre-primate stock is represented in the existing fauna by the tree-shrews (family Tupaiidæ), which are extremely primitive in many characters.

Life zone: arboreal. Locomotor apparatus: adapted for active arboreal life.

Food habits insectivorous-frugivorous.

Dental formula $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{4}{4}$ $M\frac{3}{3}$.

Incisors, canines and first two premolars all simple, with single roots, conical tips, and internal cingulum. In p^3, p^4 the internal cingulum gives rise to the internal spurs ("deuterocones," homologous with "protocones" of molars). In p_3, p_4 the posterior cingulum gives rise to the talonids; p^4 and p_4 of sub-molariform type.

In this stage the primary trigon of the upper molar has lost its triangular appearance through the division of its apex into para- and metacones and the reduction of the outer side of the crowns, including the external cingulum cusps. The secondary trigon has arisen through the development of the internal spurs, or protocones, and the division of the para- and metacones. These changes are correlated with the transverse widening of the talonids, the development of a hypoconid and its interjection between the para- and metacones in occlusion, and with the further expansion of the protocones; the talonid basins into which the protocones fit have also widened and are wider than the trigonids.

Interdental spaces between the upper molars becoming crowded by the spreading of the protocones, in correlation with which the paraconids of the lower molars become reduced.

(17) *Primitive lemuroid stage*, represented in many respects by *Pelycodus* and *Notharctus*. Eocene, North America.

Life zone: arboreal. Locomotor apparatus adapted for perching and leaping in the trees. Pes with grasping hallux.

Food habits insectivorous-frugivorous.

Dental formula: $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{4}{4}$ $M\frac{3}{3}$

Incisors and canines not aberrantly specialized. First and second premolars with simple conical cusps; third and fourth upper premolars retaining the primitive trigonal apex; upper molars tri- to quadritubercular.

In the Notharctidæ the postero-internal cusps arise by fissure from the antero-internal cusps, but in the related Adapidæ they arise in the normal manner from the internal cingulum.

Lower molars tuberculo-sectorial, with small trigonids and wide talonids.

Skull with primitive elongate face, not sharply inclined to the basis cranii.

Orbit bounded posteriorly by postorbital processes of frontal and malar.

The American Notharctidæ are possibly ancestral to the South American monkeys, but not to the Old World series, including man. Nevertheless they illustrate the transition from the primitive menotyphlan insectivorous to the primitive primate stage.

(18) *Primitive pro-tarsioid.* Represented in certain characters by *Omomys* and *Hemiacodon*. Middle Eocene, North America.

Life zone: arboreal. Locomotor apparatus adapted for leaping in the trees, but limbs not excessively elongate. Pes with grasping hallux.

Food habits insectivorous-frugivorous.

Dental formula: $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{3}{3}$ $M\frac{3}{3}$

Skull with orbits, braincase and and auditory parts moderately but not extremely enlarged.

Lower incisors gently procumbent, not enlarged. *Omomys* and *Hemiacodon* somewhat too specialized in the enlargement of the lower central incisors and other details, but in the general form of the premolars and molars they afford relatively primitive conditions for two divergent lines of specialization leading on the one hand to the New World series (Platyrrhinæ) and on the other hand to *Parapithecus* and the Old World group.

First upper and lower premolars already eliminated and second becoming very small. Third and fourth upper molars showing tendency to become bicuspid.

Third and fourth lower premolar with posterior cingulum-talonid in an arrested stage of evolution, incipient trigonids asymmetrical,

the metaconid of p_4 foreshadowing the lingual cusp of the homologous tooth in the higher primates.

Upper molars tritubercular, with conical para- and metacones, small proto- and metaconules, a cingulum-hypocone and an antero-internal cingulum.

Lower molars with small trigonids and enlarged hypoconids. An antero-external cingulum.

(19) *Progressive tarsioid.* Upper Eocene. Not in direct line but represented in certain characters by *Necrolemur*.

Life zone: arboreal. Locomotor apparatus adapted for leaping in the trees. Pes with grasping hallux, but without great elongation of tarsus of known tarsioids.

The differences separating *Necrolemur* and *Microchœrus* from any of the New World or Old World monkeys are numerous and important, and there is no evidence for deriving any of the higher types directly from this source. Nevertheless these genera exhibit certain important advances in the direction of the Old World primates, among which may be noted the development of quadrate upper molars with subequal anterior and posterior moieties; the development of hypoconulids in the lower molars; the final loss of the paraconids in the lower molars; and the tendency for the reduction of the trigonid basins, the tendency for p^4 and p^3 and the corresponding lower teeth to become bicuspid; the incipient development of a bony postorbital partition; the lateral expansion of the base of the braincase; the development of a tubular external auditory meatus; and the tendency for the angle of the mandible to be expanded and for its posterior border to become very large and rounded. Thus *Necrolemur* and *Microchœrus* have advanced far from the primitive tarsioid type and indicate some of the structural stages through which the actual ancestors of thd Old World series probably passed.

(20) *Pre-catarrhine, or super-tarsioid stage.* Represented by *Parapithecus* of the Lower Oligocene of Egypt.

Food habits insectivorous-frugivorous.

Dental formula: $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$

Lower incisors partly procumbent, not specialized.

Lower canine small, slightly larger than incisors and anterior premolars.

p^1, p^2 and p_1, p_2, lost; p^3, p^4 and p_3, p_4, retained, the latter incipiently bicuspid. Posterior premolars becoming unlike molars, losing the incipiently molariform pattern of earlier mammals.

Lower molars with low, conical cusps, the talonid about as high as the trigonid. Paraconids lost, the four remaining cusps grouped into two pairs. Hypoconulids or mesoconids present.

The construction of the lower molars indicates that the upper molars were quadrate, with the anterior and posterior cusps arranged in two pairs.

Body of mandible and ascending ramus not so broad as in later members of the anthropoid-man series.

Skull unknown.

The direct derivation of *Parapithecus* and the Old World series not known. The tarsioids foreshadow them in certain respects, such as the loss of the anterior two premolars, but all known tarsioids are excluded from direct ancestry by specialization of the front teeth, of the orbits, and of the lacrymal region. Nevertheless it is probable that the unknown predecessors of *Parapithecus* might be included in a widened definition of the Tarsioidea.

(21) *Primitive anthropoid stage.* Represented by *Propliopithecus* of the Lower Oligocene of Egypt.

Food habits frugivorous-omnivorous.

Dental formula: $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$

Incisors not specialized; canines considerably larger than incisors, but crown of lower canine not very high.

Premolars bicuspid; molars with four main cusps arranged in two pairs; hypoconulids median.

The dentition of *Propliopithecus* is structurally ancestral to that of all the higher apes and man, as noted by its discoverer, Schlosser.

(22) *Advanced pre-human anthropoid.* Middle Tertiary. Represented by *Sivapithecus* and *Dryopithecus*. Miocene of India and Europe.

Food habits frugivorous-omnivorous.

Dental formula: $I\frac{2}{2}$ $C\frac{1}{1}$ $P\frac{2}{2}$ $M\frac{3}{3}$

Lower incisors with crowns not widely expanded.

Lower canine with pointed, erect tip.

Lower anterior premolar with slightly flattened anteroexternal face, articulating with large upper canine. Posterior premolars bicuspid.

Lower molars with four main cusps arranged in two pairs; stout median hypoconulids.

Lower molars with "*Dryopithecus* pattern;" paraconids absent; trigonid basins reduced, talonid basins expanded. Upper molars m^1 and m^2 quadritubercular.

(23) *Human precursors.* Pliocene. *Pithecanthropus* of the Pliocene or Lower Pleistocene (?) of Java possibly a representative. Skull top of very low type, much like a greatly enlarged gibbon skull. Forehead extremely low and retreating, supraorbital tori protruding far in front of narrow frontal region.

Two upper molars found in same stratum but further down stream and referred to individual represented by skulltop.

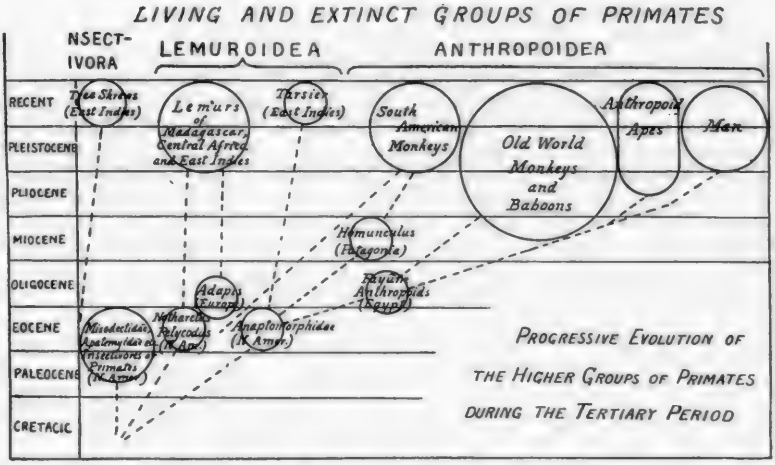


FIG. 345. PHYLOGENY AND GEOLOGICAL SUCCESSION OF THE PRIMATES. AFTER MATTHEW

Third upper molars very large, of advanced anthropoid or primitive human type.

Large femur found in same stratum supposed to indicate erect gait.

(24) *Heidelberg race.* Lower or Mid-Pleistocene, Europe.

Mandible of great size, with very massive body, very broad ascending ramus and backwardly-sloping chin. Dentition of primitive human type with tips of incisors and small canines on same level with premolars and molars.

Molar-cusp formula: $\frac{5}{5}, \frac{5}{5}, \frac{5}{5}$

Molars moderately taurodont.

Skull probably of pre-Neanderthal type.

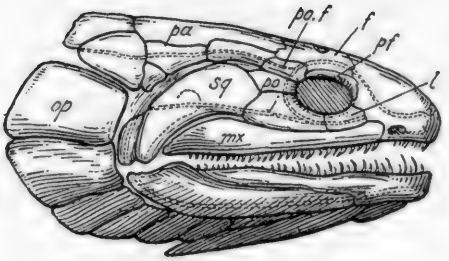


FIG. 346

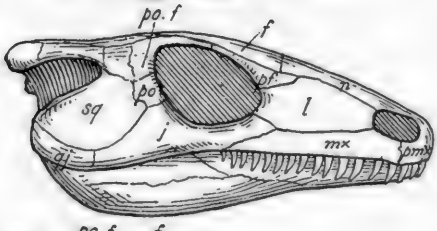


FIG. 347

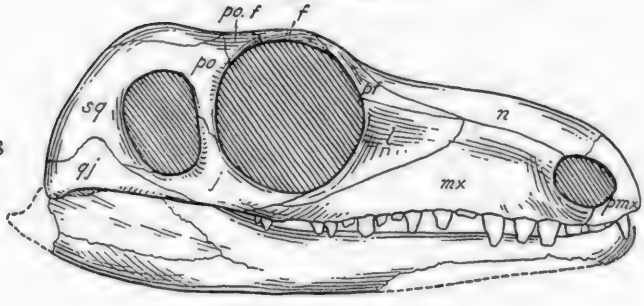


FIG. 348

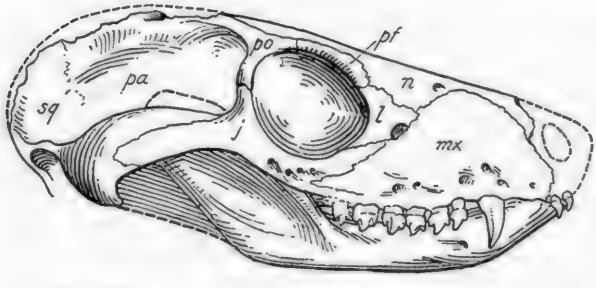


FIG. 349

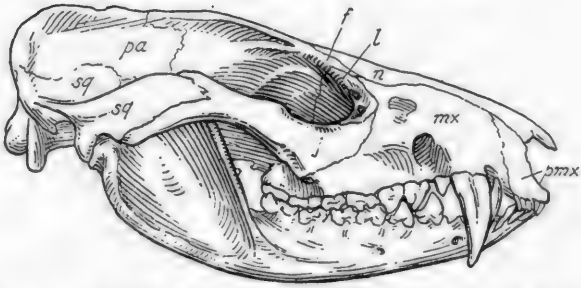


FIG. 350

FIGS. 346–353, INCLUSIVE. STAGES IN THE EVOLUTION OF THE HUMAN FACE AND DENTITION. COMPARE DESCRIPTION OF STAGES ON PAGES 206–218, ABOVE

346. Stage 3. Primitive Devonian crossopterygian fish, *Osteolepis*. After Goodrich.
347. Stage 7. Primitive Permian cotylosaurian reptile, *Seymouria*. After Williston.
348. Stage 9. Primitive Permian pelycosaurian reptile, *Myclerosaurus*. After Williston.
349. Stage 12. Advanced Triassic mammal-like reptile, *Ictidopsis*.
350. Stage 13 *bis*. Primitive metatherian (here represented by a modern opossum).

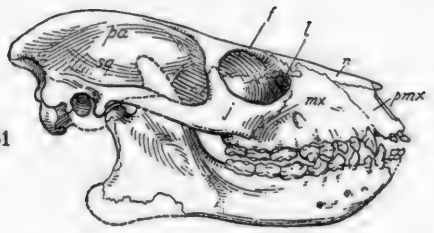


FIG. 351

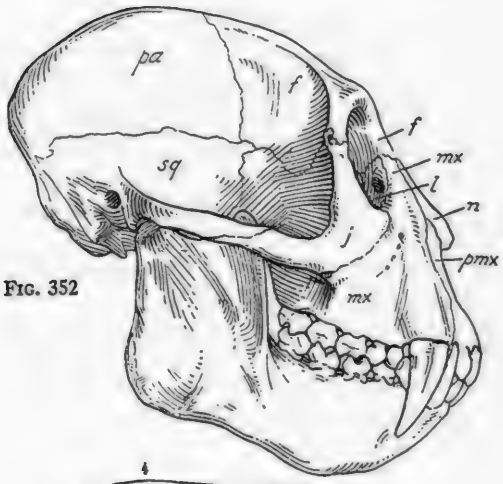


FIG. 352

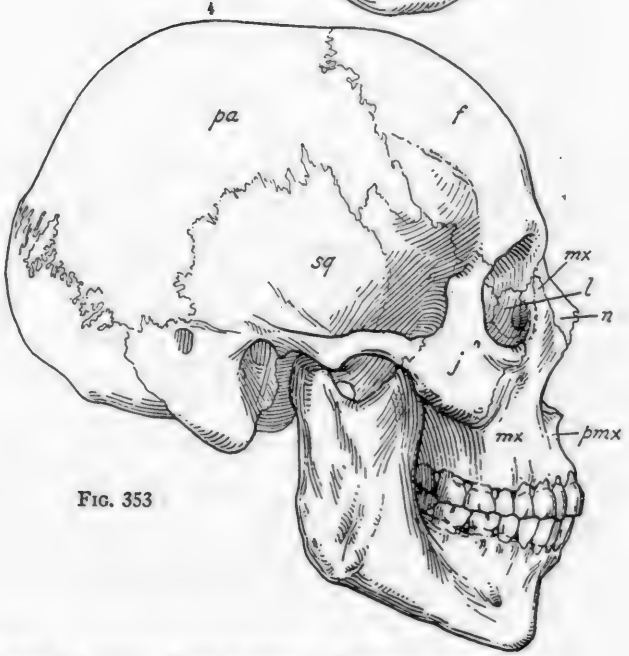


FIG. 353

351. Stage 17. Primitive Eocene lemuroid, *Notharctus*.
352. Stage 20. Primitive catarrhine (here represented by a modern macaque).
353. Stage 26. Modern man, *Homo sapiens* (Chinese)

(25) *Low human type.* Example: the "Mousterian youth."

Skull large, with very low forehead, dolicho., with great supraorbital tori, and very large prognathous face, with enormous platyrrhine nose. Chin retreating. Skull narrow anteriorly and broad posteriorly.

Incisors with edge-to-edge bite.

Molar teeth moderately taurodont. Premolar- and molar-crown patterns retaining many simian or primitive details. Second lower molars with five cusps and *Dryopithecus*-pattern. Second upper molar with four cusps, projecting hypocone.

(26) *High human type.* Example: *Homo sapiens nordicus.*

Skull with steep forehead, secondarily (?) dolicho., with no supraorbital tori.

Face orthognathous, long, with delicate, straight, narrow nose. Chin prominent. Incisor overbite.

Molar teeth short-crowned. Second lower molar with four cusps and +-shaped pattern. Second upper molar with three cusps, i.e., hypocone greatly reduced or absent. Third upper and lower molars greatly delayed in eruption, often failing to erupt at all.

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REPARATIVE CHANGES THAT TAKE PLACE ABOUT THE ROOT-ENDS OF INFECTED PULPLESS TEETH, AFTER TREATMENT

A Report of Cases From Practice

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New York City

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I. INTRODUCTION

That certain changes of a reparative nature take place about the root-ends of infected teeth as a result of treatment, by which they are apparently restored to health, as shown by comparative roentgenographic study, is no longer a subject for speculation. It is a fact susceptible of proof. What the exact nature of these changes is, what form of treatment is best adapted to produce them, and what conditions make for or against success, are questions which cannot be fully answered in the light of present knowledge. It is a fact, however, that under certain forms of treatment, including sterilization and root filling, many teeth showing marked periapical disturbance are apparently restored to health. Experience in clinical and roentgenographic examination has shown that when pulpless teeth are treated with sterilizing agents in such a way as to produce comparatively little injury to the periapical tissues, and when the root canals are filled to the end so as to seal them (all being done under aseptic conditions), excellent results are achieved.

The difficulties in the way of success would seem to be not so much in the form of treatment, as outlined above, as in complying

with the conditions essential to success; and in being certain that they have been complied with in any given case. Where these conditions can be met with reasonable certainty (which is possible with most single rooted teeth, and, to a less extent with multi-rooted teeth) and where the case history is such as to justify conservative treatment, it is not unreasonable to believe that such teeth can be safely retained.

For the purpose of showing what may occur about teeth periapically infected, a few cases from practice, in which the prognosis was unfavorable, have been chosen to illustrate some of the reparative changes which take place, when the conditions above mentioned have been complied with. The case histories are given for the purpose of throwing as much light as possible on one of the most complex problems in dental practice.

II. CASE HISTORIES

Case 1. Age thirty-eight. Infected upper lateral incisor. Systemic symptoms suggestive of focal infection. *Fig. 1* shows the tooth as roentgenographed on November 19, 1918. *Fig. 2* shows changes which had taken place on November 4, 1919. It will be observed that complete regeneration has taken place in the periapical tissues. There was also disappearance of all systemic symptoms.

Case 2. Age seventeen. Cyst due to gangrenous tooth-pulp in lower right lateral incisor. History of occasional neuralgic pains on the right side of the face extending over a period of three years—the first molar had been extracted in an attempt to locate it. First seen January 25, 1919; *fig. 3* shows a roentgenogram made on that date. Note the clearly defined outline of a cyst cavity. Subsequent to opening the tooth, acute symptoms developed with swelling of the face and discharge of pus through the tooth. These symptoms disappeared; after treatment, the tooth was filled on February 27, as shown in *fig. 4*. *Fig. 5* shows results on June 14, 1920. All evidence of the existence of a cyst cavity had disappeared, and no further symptoms appeared.

Case 3. Age forty-two. Right upper first bicuspid with a so-called "blind abscess." Extraction was advised. Attempt at saving the tooth was urged by the patient. *Fig. 6* shows a roentgenogram with a measuring wire in place on November 13, 1916. Note complete loss of bone in the apical area. After treatment, the tooth was filled on December 11, as

shown in *fig. 7*. *Figs. 8, 9* and *10* show progressive changes that took place up to June 10, 1920. The tooth has remained free from symptoms since treatment.

Case 4. Age thirty-nine. Lower left second bicuspid. Fistulous abscess, but no local or systemic symptoms. As the tooth was an abutment for a fixed bridge, treatment was urged by the patient. *Fig. 11* shows a roentgenogram taken November 24, 1917. Observe the large abscess cavity and the eroded appearance of the root end. *Fig. 12* shows the tooth as filled on January 28, 1918. The results of treatment are shown in *fig. 13*, taken January 5, 1921. Also note the improvement in the first bicuspid.

Case 5. Age forty-seven. Right upper lateral incisor. Blind abscess as shown in *fig. 14*, November 4, 1915. General symptoms, suggesting focal infection. No local symptoms. On opening the tooth, a watery discharge followed introduction of the instrument. Cultures made by the Research Laboratories of the New York Health Department showed a low grade staphylococcus. After treatment, the root was filled, November 30, 1915. All secondary symptoms disappeared. *Figs. 15* and *16* show the processes of repair that had taken place, respectively, on February 1, 1917 and January 22, 1921.

Case 6. Age forty-four. Blind abscess involving central and lateral incisors, cuspid and first bicuspid, as shown in *fig. 17*, taken March 12, 1918. First bicuspid was extracted; the others were opened and treated. As the patient lived at a considerable distance, the roots of these teeth were not filled until November 13, 1918, as shown in *fig. 18*. Note the relation of the abscess cavity to all four teeth as shown in this roentgenogram. These teeth were crowned; four months later, March 28, 1919, another roentgenogram was made, as seen in *fig. 19*. It will be observed that repair in the apical area is already under way. Because of the distance at which this patient lives, later roentgenograms have not been made to date.

Case 7. Age twenty-seven. Pulpless lower second deciduous molar which had been retained owing to congenital abscence of second bicuspid. *Fig. 20* shows a roentgenogram made December 2, 1919. Acute symptoms of pain, swelling and discharge of pus, followed opening of the tooth. After treatment, the roots were filled February 16, 1920. No symptoms appeared since filling. *Fig. 21* shows the extent to which repair had progressed on January 13, 1921, less than one year after the case was dismissed. The unique feature of this case was the fact that the tooth under treatment was a deciduous molar.

Case 8. Age thirty-six. Upper lateral as shown in *fig. 22;* roentgenogram taken May 10, 1919. Clearly defined apical area of radiolucency, with a perforation made in attempts to remove the root filling. *Fig. 23* shows the result, January 22, 1921. This case is shown because of the complication caused by the perforation. The root was filled in the usual way, no attempt being made to fill the false canal. The tooth has been wholly free from symptoms since filling.

In all cases, tricresol and formalin, as advocated by Buckley, were used for sterilization. No other treatment was employed. Three to five treatments were made. The root canals were filled with chloro-percha and gutta-percha points. All were cases in which the prognosis was regarded as unfavorable and treatment was undertaken with some misgivings. For this reason these cases were kept under observation. In no case has any local or systemic symptom developed, since treatment, that would indicate continuance of infection in these teeth. These cases are reported here for the purpose of showing what may occur in periapically infected teeth, under initially adverse conditions, after treatment.

III. GENERAL CONCLUSIONS

These results can undoubtedly be multiplied indefinitely and, in cases less marked, similar results are of almost daily occurrence, pointing clearly to the fact that, under certain conditions, pulpless teeth may be restored to health and usefulness. At least, these results indicate that no one may presume to be arbitrary in the matter. Indiscriminate extraction, as practised by some, would seem to be as unwise as indiscriminate attempts at saving all pulpless teeth. Sterilization by approved methods, and the filling of root canals to the end, appear to be the prerequisites to success in the treatment of pulpless teeth. Where these prerequisites can be met, and where there are no serious systemic complications indicative of focal infection, there is accumulating evidence that pulpless teeth can be safely retained.

ADDENDUM

Since the foregoing was presented to this JOURNAL for publication, there appeared in this JOURNAL an article by Novitzky, a reply by Rhein, and a rejoinder by Novitzky.[1]

Novitzky's statement, that "a careful examination of hundreds of devitalized teeth has failed to show a single one that, six months after devitalization, was not infected," means only that the conditions essential to success in the treatment of such teeth had not been met. Rhein is well within the truth when he says, in reply, "that a large percentage of teeth with non-vital pulps can be so treated as to leave them free to function, without any danger of such teeth becoming factors in focal infection."

The statement that "a pulpless tooth is in every sense of the word *dead*, for its only source of nourishment has been cut off," has been proved by Box to be incorrect. Those who saw his photomicrographic slides at the meeting of the National Dental Association in New Orleans in 1919 (copies of which have not yet been published) need no other proof of the inaccuracy of the statement that a pulpless tooth is *necessarily* a "dead" tooth. That there are pulpless teeth which cannot be saved goes without saying; but to insist that all such teeth are "dead" teeth, and should be extracted, is bad teaching and worse practice.

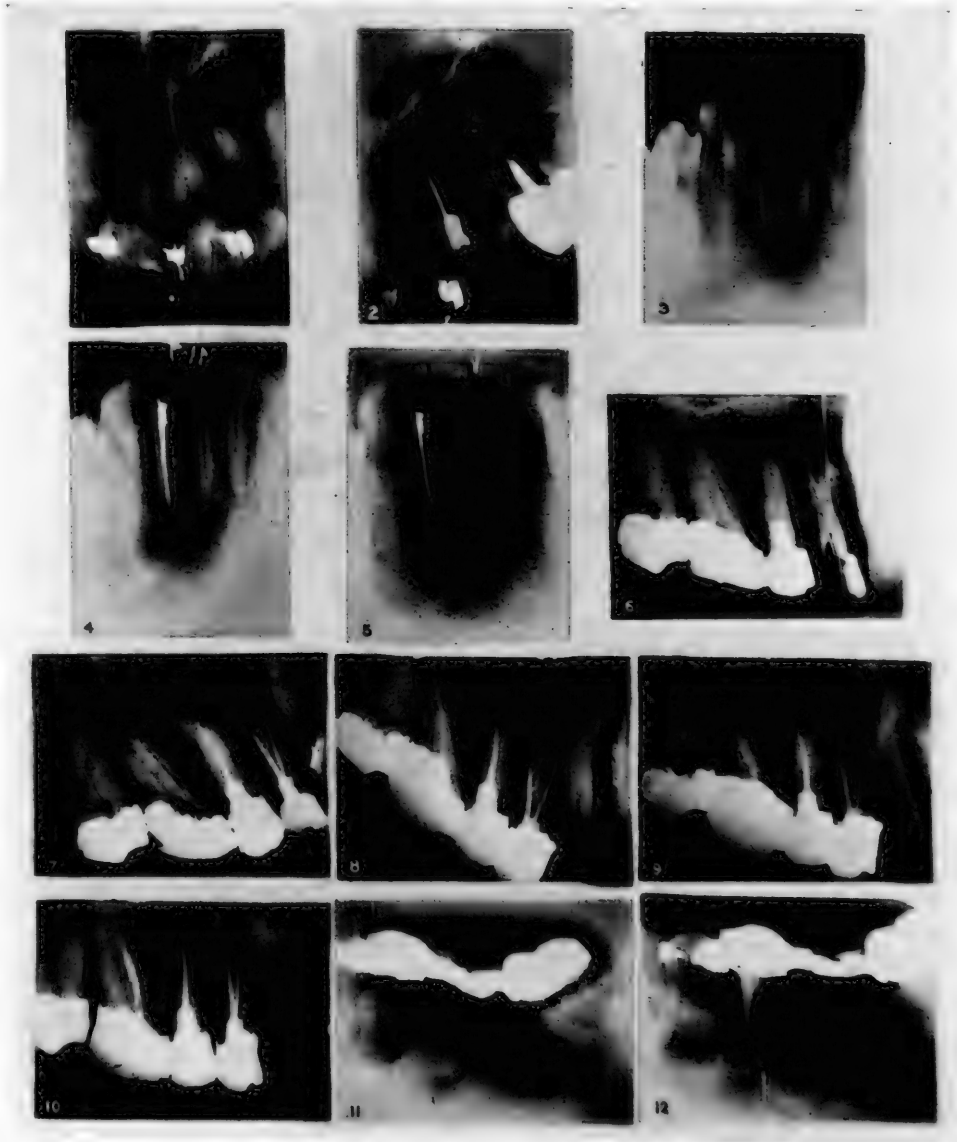
58 West 47th Street

[1] Novitzky: JOURNAL OF DENTAL RESEARCH, 1920 ii, p. 567; Rhein: *Ibid.*, p. 579; Novitzky: *Ibid.*, p. 585.

PLATES 1 and 2

FIGS. 1–13. Cases 1 to 4, inclusive. See histories, pages 230–231

FIGS. 14–23. Cases 5 to 8, inclusive. See histories, pages 231–232



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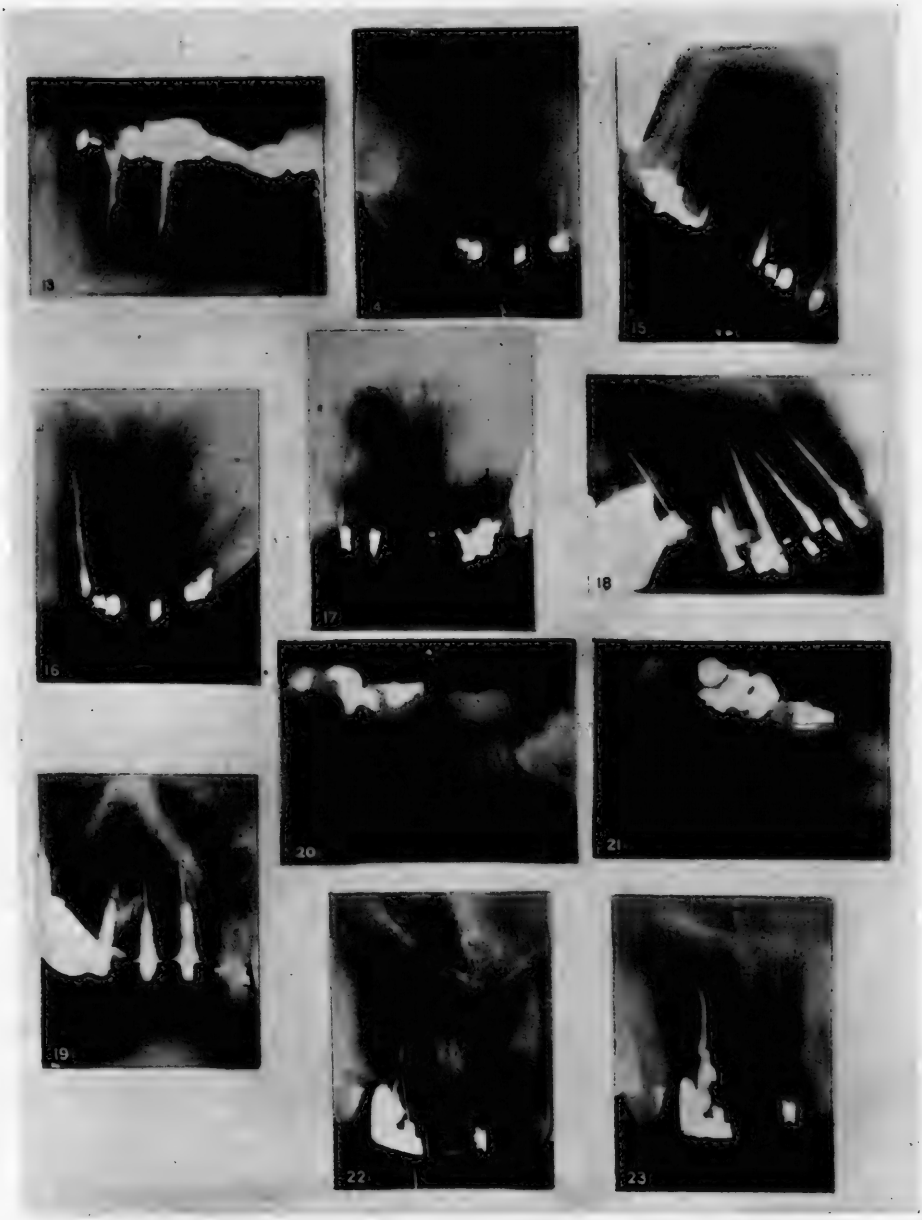

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NINTH REPORT

WILLIAM J. GIES

Subscriptions to the Endowment Fund for the support of the JOURNAL OF DENTAL RESEARCH have been received, since the publication of the eighth report (vol. II, p. 719), from the contributors named below.[1]

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[1] The numerals in parenthesis, after some of the names, indicate that the subscribers thus designated have made second (2) or third (3) annual contributions to the Fund.

We regret that few of those who conduct the business of producing and selling dental supplies have accepted the long-standing invitation, in these reports, to manifest practical interest in the development of non-commercial dental literature by contributing to the development of our Endowment Fund. Under these circumstances, it is all the more agreeable to call special attention to the generosity of the dental business men and organizations named below, who have contributed effectively to the permanent support of this JOURNAL without qualification, condition or reservation, and who have shown, by the cordiality of their specific approval, that they wish to encourage and foster the development of independent research and scientific journalism in dentistry.

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Contributions to this permanent endowment fund, *in any amounts*, are invited from *all who may be interested in the welfare and continuing success of this* JOURNAL.

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AMERICAN ACADEMY OF DENTAL SCIENCE

HORACE L. HOWE, *Editor*

Meeting held January 5, 1921. Young's Hotel, Boston, Mass. President L. M. S. Miner in the chair.

Scientific proceedings. Paper by A. Le Roy Johnson, D.M.D., Sc.D., Boston, Mass., on *"the diagnosis of malocclusion, with reference to early treatment"* (this page). *Discussion* not reported.

THE DIAGNOSIS OF MALOCCLUSION WITH REFERENCE TO EARLY TREATMENT

A. LE ROY JOHNSON

Boston, Massachusetts

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I. INTRODUCTION

I appreciate the honor conferred upon me in the invitation to read a paper before this society. It gives me the privilege of speaking for that group of men whom many of you think of as impractical idealists. While an honor drives one on, the right to speak for principles believed in is a satisfaction no one will deny. For this reason I welcome this opportunity to explain, in some degree, the viewpoint of the dental orthopedist of today.

As specialists we have made many mistakes. The literature is full of extravagant claims and, I might add, contains relatively little proof. Perhaps at times we have been impractical idealists. But our field is a new one; and, if you will look back, you will find reason to believe that many of our errors have contributed substantially to the development of the science. In the evolution of a science as in the evolution of a race, nature's processes, in retrospect, seem roundabout, aimless, and wasteful in time and energy (11). Further, just as in the development of a single organism, provisional structure is often essential in the organization of vital parts, so, also, in the development of a phase of science, false dogma often brings the truth to light. We do not stand convicted because of the errors we have made—the crime is to continue in the face of contradictory evidence.

It is not my intention at this time to present a detailed exposition of the problem involved in diagnosis. As an argument the following is very much abbreviated. Yet I hope that it will be sufficiently clear to enable you to contrast in your minds the viewpoint now held, in regard to the nature of the problems involved in the diagnosis of developing deformities, with that expressed in the literature not so very long ago; also, that it will help to dispel some doubt as to our sanity.

II. FALLACIES IN THE ASSUMPTION THAT ORTHODONTIA IS A PART OF MECHANICAL DENTISTRY

Orthodontia was once a part of mechanical dentistry. Many of you will remember when it was so treated by the dental schools. It was taught by the professor of prosthesis and, quite naturally, the viewpoint given was a mechanical one; and today the speciality is still struggling under the burden of the mechanical attitude of mind it is heir to. The ideals of mechanical perfection, so essential in prosthetic work, have created in this, another field, methods (and standards) which are most unreasonable.

At one time all treatment was deferred until after the eruption of the permanent teeth anterior to the first permanent molars. Later the claim was made that treatment should invariably begin with the deciduous denture, the belief being that if malocclusion were recognized and corrected in the infant arch, the permanent teeth would erupt in normal relation. Thus came the idea of early treatment, sound in principle, yet bringing with it a problem which we as a profession have been slow to recognize. Nowhere is this more evident than in certain methods and systems of diagnosis.

As late as 1916–'17, Bogue (2) said that "the normal child at three and one-half years of age should have an upper dental arch of at least one and ten one-hundredths of an inch lateral width in the temporary molar region." In his published report of that date Bogue refers to seven cases measuring over one and ten one-hundredths of an inch in width as being "nearly normal." In another place pictures are shown of arches which have been increased in width in the temporary molar region to over one and ten one-hundredths of an inch and these cases are referred to as having been "made normal."

The same principle has been followed by others in that they have endeavored to utilize, as the normal, a standard created by mechanical and mathematical processes. For instance, witness the methods of the exponents of arch predetermination. From the measurements of teeth and arch, supplemented by mathematics, they designate the individual denture as normal or abnormal in its development. The scheme is said to be based upon the assumption of a definite relation between the size of the teeth, and the size and form of the dental arch. The idea is attractive. It is seductive in the presence of our mechanical heritage. It offers the promise of the absolute. Yet the investigations of Hellman (7) show beyond reasonable doubt that the assumed correlation between the size of the teeth and the form of the arch does not exist.

A statement which has been often quoted is the assertion that "unless a perceptible spreading apart of (the) baby teeth begins to take place before the third year of the child's life, the prognosis for regularity among the permanent teeth is unfavorable; and if at the age of four years, the breadth of the upper dental arch between the lingual sides of the second temporary molars, at the gum margin, is not at least equal to 28 mm., it is absolutely certain that the child has already suffered an arrest of development which it cannot surmount and will not outgrow unaided."

Of course, today, few would accept such an idea in its literal interpretation. Nevertheless not so very long ago it was accepted by many in the profession because it presented a definite scheme of diagnosis, mechanical in its precision. But can it be assumed that in order to be normal an arch must be a definite size to the millimeter at a specified age, chronologically? The evidence is to the contrary. Jaws do grow and develop without the aid of orthodontic appliances. All children do not need treating. Yet there is a great deal in the literature, in reference to methods and principles of diagnosis, which gives the impression that as specialists we have held nature's processes in light respect.

At the outset I wish to make it clear that we *do* believe in early treatment *most sincerely*. Anyone who has had experience enough in orthodontia to qualify as a specialist, can not close his eyes to the fact that there are deformities which must be treated early if a result is to be obtained which is at all satisfactory. No one will question the fact that treatment should begin "as soon as possible after the discovery of abnormality." We do not criticize the principle; *we question the conception of the normal, the standard of comparison and judgment, which often determines diagnosis and stamps conditions as abnormal, needing treatment.*

As we go nearer to the beginnings of abnormalities the signs become more indistinct, requiring a careful consideration of phenomena to ascertain their significances. Hence, in raising this question of the normal, it is necessary to run the risk of being tedious and to give in detail our idea of the purpose of orthodontia, as well as an analysis of the meaning of normal as we interpret it in diagnosis.

III. ORTHODONTIA IS BASED PRIMARILY ON PHYSIOLOGY RATHER THAN SOLELY ON MORPHOLOGY

We believe that the purpose of orthodontia is to correct those occlusal relations and malpositions of the teeth which interfere with the normal functional activity of the dental apparatus. The word function we interpret in its broadest sense. It is commonly used to convey the idea of the specific activity of a part, as the digestive function of the stomach, the secretory function of a gland, or the masticatory function of the teeth. But its broader physiological definition means all of the dynamic processes of living tissues; the complex of chemical reactions; the action, reaction, and interaction of organs and parts in the adjustment of life. Hence, in treating orthodontia as an art concerned with the functional activities of the dental apparatus, we mean not only mastication but also all of the vital processes of the surrounding structures, and the interaction of these parts in the life activities of the whole organism. It is in fact dental orthopedia.

This conception of the field of orthodontia is by nature physiological. Even though we recognize the fundamental unity of function and structure, the approach to problems of deformities of the dental arch from the standpoint of function is in accordance with the principles of science, and is quite different from the point of view which considers deformities from the standpoint of the mechanics of structure alone, and which for our present purpose we will refer to as morphological.

The morphologist in orthodontia designates the vault of the palate as normal or abnormal on the basis of its comparison with his idea of the best-formed palate for the human being. He believes that the small nasal space of the mouth-breather is due to the narrow dental arch, and claims that widening the dental arch, because it is the floor of the nose, will give more breathing space. In a sense this may be true. Nevertheless from the standpoint of science, success attending such operations, when the success is measured by the return of normal respiration, is often accidental and misleading. The morphologist in orthodontia believes that the teeth can be put in most any form of arch, and, if retained long enough in that position, will remain there throughout the life of the individual. But such an attitude overlooks a fundamental principle of biology *that the form of structure is the result of the interaction of function and structure, and that in the ultimate, function is the determining factor of form* (10). The physiologist in orthodontia recognizes respiration as the vital factor in the development of the nasal space; he sees in the dental arch a mobile equilibrium, reflecting the inheritance and life activities of the organism as a whole; and he realizes that successful treatment depends more upon an interpretation of the forces expressed in the structural modification of deformities than it does upon a knowledge of the mechanics of occlusion and biometrical data. To the physiologist bone is not like cement; it does not become fast, permanent and stable with age. Living bones feel hard and rigid to the touch of hand or instrument yet they are highly plastic structures. As Hall (6) says, they are "the framework of the body only in a mechanical sense; their development is not only later than the soft parts but is dominated by them. Bones like all other tissues, are composed of cells, penetrated by nerves and blood vessels, are very plastic both to normal forces of growth and to external influences, and are subject to many diseases." Thus in orthopedia, where we would correct deformities the physiological point of view is essential because the problem is by nature physiological, and the concept of the normal must conform to the nature of the problem.

An analysis of the normal furnishes the groundwork of all diagnosis. It makes clear the nature of the problem and the difficulties attending its solution. Webster refers to normal as a standard. In biological science the nature of the standard depends upon whether the problem is one of species, or whether it is a question of the interaction of the constituent elements of the individual organism. In illustration of the former I quote from Dwight (4), in a chapter on "variations and anomalies." He says: "There is *normally* in the human shoulder blade a little projection from the

lower part of the front border." In another place he says: "There are also anomalies of tissue in which a certain structure that is usually of one material is made of another, as when what is *normally* a cord is made of a bone or cartilage." Again: "Now I found this form of muscle in both arms of the chimpanzee, and MacAllister observed it once in the tiger, though it is *normal* to neither." Here, as is usual in the field of morphology, "normal" refers to a condition characteristic of the majority of the individuals of a group, race or species. There are exceptions but the rule is that the condition prevails. It signifies a standard determined by the constancy, the prevalence, the frequency of the occurrence of a condition in the different organisms of a species. It is a standard of numerical frequency, and for the sake of clearness we designate it as the collective or species normal.

But when the problem is one of the relation of an organ or part to the individual organism the standard to which normal refers is of a different kind. It implies a criterion of a functional nature. It refers to a condition which expresses the most stable organization of the being as a whole. The standard is a physiological one. If you would know whether the weight of a child is normal or abnormal not as compared with other children, but for the individual child itself, the problem is one involving all the vital processes and functional activities, local and general. Merely weighing the child is of little value and means nothing unless the weight is correlated with height, vital capacity, physiological age, general form of structure, and metabolic processes. The significance of the reading of the scales is derived more particularly from a study of the vital processes of the whole individual than from comparison with other children.

Now apply this interpretation of normal to developmental conditions of the dental arch. If you measure the arches of a group of children, and find that the majority show 2 mm. in width between the second deciduous molars, you establish the normal width for that group of children. In other words you have ascertained the collective or species normal. To measure the arch of one child will show how it compares with the arches of other children. In like manner you can compare other characters, such as the length of the over-bite with the same condition in other children. But of what value is such comparison in deciding whether or not the dental arch of the child is normal for that particular child?

This question brings up the subject of type in the study of the individual. A great deal of the misconception of the nature of the normal, expressed in the abortive attempts to create systems of diagnosis upon a basis of linear measurement alone, is due to a lack of appreciation of what

type is and its significance in diagnosis. In prosthodontia, where artificial representations of type in the forms of teeth are made practical use of, the word has a very different value than in the field of orthodontia. On account of the intimate relation of the idea of type, and the definition of normal, a knowledge of one is dependent to quite an extent upon a knowledge of the other.

We have often heard of the dolichocephalic type, the long head; and the brachicephalic type, the broad head. And the contention has been that with the long heads, there is the long arch; and with the broad heads, the broad arch. But there is more to the consideration of type than this. In fact it has been established that the relation in the individual between head form and arch form, as we meet people today, is a correlation that is very obscure (9). It should be remembered that there is no absolute line of demarcation between the long heads and short heads; and that here in America, where all races are intermingled, the large majority would undoubtedly fall somewhere between the well-defined groups.

Type refers to an abstraction, determined by the extent and direction of individual variations. Literally it is the ideal representation of a group of natural phenomena. It refers to a general form or plan of structure common to a number of individuals. It is the result of bringing together, of combining in one concept, a variety of conditions, each different from the other, no two alike. It is not a concrete thing existing in natural form. It is a model or pattern from which each individual presents some degree of variation. The concept of type defines certain limits of variation since the criterion of function is adaptation—physical, psychical and social. When an individual is referred to as typical the idea is that as a whole he possesses certain characteristics common to a race of people. It does not mean that he conforms in all particulars to the image of the ideal. Measuring the arches of a group of children is one step in the creation of the concept of the typical dental arch. In obtaining the normal of another character, as the length of over-bite, the cases which are nearest alike will not necessarily be the same as those which constitute the majority in the matter of arch width. Consequently while for a group we can determine the normal width, over-bite or arch form, etc., and having done so are able definitely to describe the typical dental arch, it should be clear that the typical dental arch is not a concrete thing, but that it is an ideal pattern from which each individual presents some degree of variation. Type is then an abstraction; it is a guide in the study of the normal; it is not to be taken as a definite measure of normality. Normal, as it signifies the condition of a part of an individual organism, refers to a balance of functional activity best suited to the adaptation of that individual as a whole.

It is not our business to make the arches of different children conform to one standard of form and measurement. Nor can we reconstruct a child around its teeth. The dental arch is an interdependent part of the living child, and so reflects in its development the influence of the hereditary, pathological, and environmental factors which characterize the individuality of the whole, and which set bounds beyond which the effect of orthodontic treatment can not pass.

IV. DIAGNOSIS IS A PROBLEM OF NORMAL VARIATION

Diagnosis is a problem of normal variation and, as such, is a question which can not be answered in the absolute. A line can not be drawn with mathematical certainty between the normal and the abnormal, as they refer to the interaction of the different organs and parts of an individual. Especially is this true in the case of conditions so indefinitely defined as those in the incipient stages of developing malocclusion. To assess the value of slight variations is one of the most difficult of tasks. And today no one would attempt to lay down specific rules of diagnosis with the idea of indicating absolutely, in all cases, the normal and the abnormal. Much of the knowledge necessary for the execution of such a scheme is still of that vague and indeterminate kind that eludes expression. Yet enough has already been crystallized to establish a point of view consistent with modern scientific thought, and at variance with that expressed in the belief that an abnormal arch is one that does not conform to an ideal standard of mechanical perfection.

Diagnosis is inseparably associated with a knowledge of causation. Etiology is the weakest chapter in orthodontia. Compared with treatment it occupies very little space in the literature. So long as this condition prevails one can not deny the conclusion that much of the treatment advocated is empirical rather than rational. And it will continue to be so until more serious attention is paid to the problems of causation.

The tendency has been to attribute most conditions of malocclusion to so-called local mechanical causes. The relation of mouth-breathing to maxillary deformity has long been explained as the expression of disturbed muscular and atmospheric pressure; open-bite as the result of tongue habits; spacing between the teeth as due to over-sized tongue. I might cite other instances which reveal a mechanical attitude of mind toward problems of etiology.

Whereas no one will question the fact that abnormal action of the muscles of the tongue, lips, or cheeks will modify the form of the dental

arch, the attempt to explain all abnormities upon such a basis alone ignores the consideration of principles fundamental in diagnosis. Take for example the etiology of the distoclusion case, Angle Class II. This condition has been said to be the result of abnormal muscular and atmospheric pressure due to mouth-breathing; others claim it to be the result of improper exercise of the muscles in bottle-feeding. But such hypotheses have contributed little. To recognize a relation of the mechanics of muscular activity to distoclusion does not necessarily indicate the factors involved in the development of the deformity. In most instances this relation is nothing else than a correlative variation of parts. Although the difference in the relative positions of the teeth in the two divisions of Angle Class II may be explained upon the basis of tongue and lip function, there is no suggestion in such an explanation of the disharmony of parts responsible for this diverse action of the muscles. Mouth-breathing is not consistently associated with the same class of deformity; the exceptions are too many to accept it as a cause, in the physical sense of the word, of the distoclusion case.

The face has evolved with the functions of mastication and respiration. The perversion of either or both of these functions will result in some degree of modification of the structure of the jaws. This is the law of biology. Moreover we know that malnutrition and abnormal activity of the ductless glands affect the growth and development of the jaws as they do other parts of the organism. But, if our diagnosis is to constitute a basis for rational treatment, we must account for the peculiar forms which the structures assume as a result of the perversion of function or malnutrition. How are we to account for the distoclusion; the mesioclusion or the neutroclusion case; and is our attitude to be the same toward all conditions of malocclusion as regards early treatment?

The answer to this question can only be derived from a knowledge of the phenomena of the growth and evolution of the structures of the human face; and also from the consideration of the laws of heredity, variation, habit, and adaptation. To one who observes and studies, the wonder is not that early diagnosis is a complex problem but that it has so long been thought to be so simple. A brief survey of certain groups of phenomena will, I believe, convince the most skeptical of the truth of this statement.

The fact of variation has a wider significance, in diagnosis, than merely difference in structural form and relations. Variation is evident in function as in structure. Variability in the time of developmental phenomena is everywhere evident. Tabulations of growth all show that acceleration extends over several years. The time of the appearance of pubescence

is very variable. Crampton found this factor appearing in boys from the age of 12.75 to 16.25 years of age. That variability is fully as great in dentition is shown by all tabulations of data on the period of tooth eruptions. We must accept the fact that degrees of development can not be considered upon the basis of chronological age alone. This means that, on account of the inevitable and the normal variability of the phenomena of development, a definite epoch of time, such as six, seven, or ten years, does not imply the same conditions in different individuals. Physiological age is a phrase used to signify a certain stage or degree of development, whereas chronological age refers to existence in time. The factors which determine physiological age are height, weight, vital capacity, muscular strength, the development of organs and parts; in fact, any and all of the indications of the series of changes which an individual undergoes in passing from the embryonic state to maturity.

Now when it is said that "if at the age of four years the breadth of the upper dental arch is not at least 28 mm. it is absolutely certain that the child has suffered an arrest of development," or that "perfectly close regular teeth at five years of age constitute a marked deformity," the assumption is that at four and five years the jaws of all children are at the same stage of development. That such a premise is obviously unsound needs no argument A review of the tabulations that have been made by Rose, Boas, and others, of the time of tooth eruption and variabilities, the work of Beik upon "physiological age and school entrance," all show conclusively that physiological age is the only scientific basis for the study of the individual. If the lower first permanent molar does not appear at exactly six years of age we do not forcibly erupt it. We recognize a normal variability in the time of its eruption. If spaces have not appeared between the deciduous teeth at five years of age we do know that they will not appear at five and a half years. The form of the dental arch of a child is not that of the adult, and the attempt to make it so, which means interference with the structural conditions and relations characteristic of the child's denture, will pervert factors fundamental and essential to normal development later on. Inasmuch as the range of normal variability must be interpreted upon the basis of physiological age, diagnosis must be comprehensive enough to weigh evidence of processes indicative of the stage of development the child as a whole is passing through. Thus we can not believe that an examination which only takes into account the interproximal spaces at five years, or the width of the arch at four years, will necessarily reveal developing malocclusion.

V. THE IMPORTANCE, IN DIAGNOSIS, OF THE EVIDENCE RELATIVE TO THE EVOLUTION OF THE FACE AND JAWS AS REVEALED IN THE RACE HISTORY OF THE SPECIES

Another very significant source of knowledge which must be taken into consideration, in diagnosis, is the evidence relative to the evolution of the face and jaws as revealed in the race history of the species.

Evolution does not stop with the creation of perfect form. The human organism of today is not the organism of prehistoric times, nor are homologous parts necessarily of the same value in man as in the lower animals. In the adaptation to changing conditions there is "dwindling and final evanescence of organs which are disused, due to the fact that the nutritive material is all needed by the other organs which are in constant use." (5) Certain organs develop and atrophy in the adaptation of the whole. This is the Law of Economy of Growth. Therefore it is necessary to consider the organism as a whole in the endeavor to determine the normality of any of its parts, a fact often disregarded by specialists.

The perfect mechanical adaptation of the teeth in occlusion seen in the lower animals is not as essential to life in man. How long would a muskrat live in wild life without teeth? Whereas in the lower forms, life often depends upon occlusion and so is a dominant factor of survival, in man this is not true in like degree. And because of this, from the standpoint of orthodontia, conditions governing occlusion in the lower animals are not comparable with the human in all particulars.

In fact the human being is in a sense different from all other organisms. Notwithstanding that the laws of general biology apply to all living things, it is true that in the endeavor to determine the nature of a part of the human organism, the center of interest must be the human organism itself. The degree of mental development over other forms of animal life is so great that the human being is subjected to different forces of selection in its evolution, which renders certain comparisons with other animals of doubtful value. Indeed there is a feeling among scientific men today that there is need of a separate science of human biology. J. Grasset, of Paris, has presented an outline of what he believes should be the scope of such a science. He emphasizes the difference in the life history of the human being from all others. The food habits, the conditions of survival, the development of the nervous system, biological laws of family and society, protection, assistance and defence, all signify a different sphere of activity from organisms lower in the scale of life. Furthermore, a human biology would point to a difference in the structural form and functional values of homologous parts.

Thus our concept of the normality of the human denture must be derived as much from an appreciation of the evolutionary significance of the human denture as from comparison with conditions found in the lower animals. A review of the phylogeny of the human face and jaws is not necessary before an audience of this character. Suffice it now to say that the evidence of science indicates that it is more reasonable, in the diagnosis of malocclusion, to assume the possible existence of natural disharmonies in the structural relations of the human jaws than to proceed upon the belief that the degree of perfection seen in the majority of the lower animals characterizes the development of the human dental apparatus. It is of interest to note, here, an observation by Sir Arthur Keith, in his "Antiquity of Man." He says: "In England during the Anglo-Saxon period, the incisor teeth met edge to edge in a majority of the inhabitants; the overlapping bite was exceptional. The edge to edge incisor bite occurs in all primitive human races; it is also the simian form. In a thousand years or less, then, a very remarkable change has appeared in the bite of the English people; the overlapping incisor bite has become the prevalent form. With the change has come a marked tendency to contraction of the palate and to irregularities in the arrangement of the teeth." The clinical experience of many specialists who have measured the results of their work by *the observation of cases two and three years after all appliances have been removed*, conforms to this statement of Keith's, namely, that the over-bite seems to be a racial character that is undergoing such rapid modification that in the individual it is very variable. This, then, is one instance wherein phylogenic evidence is a factor in diagnosis.

VI. THE IMPORTANCE OF THE FACTS OF EMBRYOLOGY IN AN UNDERSTANDING OF THE ETIOLOGY OF MALOCCLUSION

One of the most promising as well as one of the most neglected fields in science for the study of the etiology of malocclusion is embryology. If we follow the development of man before birth we find that deformities in later life are often comparable to conditions which are normal in embryo. During the growth and development of different parts each period is true to itself; a form of structure normal for one period may be and usually is abnormal for another. Biological investigations in other fields have substantiated this fact that variations often reflect embryonic stages of development; that they represent inhibitions of natural processes.

The study of embryology as a scientific avenue of approach to questions of maxillary deformities is particularly well illustrated in the distoclusion

case. In a chapter entitled "summary of the development of the human embryo and the differentiation of its external form," Keibel says (8): "Finally, the profile view of the head of a foetus may be shown and in it I would draw especial attention to the projecting upper lip and the receding chin, to the double lip and to the shape of the nose. In the first half of the third month the two lips project about equally, but later the border of the upper lip and the lip itself grow more rapidly, so that in the fourth and fifth months it projects markedly beyond the lower lip; by a stronger growth of the lower jaw and lip this difference is gradually overcome in the sixth to the ninth month, but by a kind of inhibition process the early foetal arrangement may be retained in the adult to a marked degree. Retzius has given especial attention to the time of the occurrence of individuality, and comes to the conclusion that in man it is recognizable even in the fourth month of intrauterine life, and becomes more marked in the succeeding months."

Such material is full of stimulating thought. I venture but this speculation. When viewed in the light of the newer knowledge of nutrition it seems reasonable to believe that the relation of bottle-feeding to deformities of the dental arch is due to a condition of malnutrition rather than to a lack of muscular exercise. The substitutes for mothers' milk are not as well adapted to the growth requirements of the tissues; whereas, on the other hand, the development of the jaws, during the greater part of the nursing period, is not sufficiently dependent upon the stimulus of muscular activity to consider it a determining factor of development. We know that malnutrition results in an inhibition of natural processes. Thus it might well be the primary factor of causation in the development of certain cases of distoclusion, because of its inhibitory effect upon that stronger growth of the mandibular structures which Keibel says is characteristic of the developing organism at birth. Of course the factors responsible for the inhibitions in other cases may be beyond our reach; yet to ascertain the time in life when the condition that is abnormal after birth is normal in the foetus will indicate the period during which the inhibition takes place, and so bring us nearer to the goal we seek—prevention.

In diagnosis we have, on the whole, ignored embryological evidence in our efforts to explain all upon the basis of mechanics, and in so doing have passed by that which, more than all else, will help us to recognize the difference in the nature and significance of deformities essential to rational treatment.

VII. THE BEARING OF HEREDITY ON DIAGNOSIS

Back of all our diagnosis is the fact of heredity. Although in all probability deformities are for the most part due to environmental influences, it is clear that the directing factors of growth are in the germ-cell. Environmental forces exercise chiefly a stimulating, inhibiting, and modifying influence. Conklin (3) says: "The entire organism develops out of the germ and the organization of the germ determines all the possibilities of development, though the actual realization of any possibility is dependent upon environmental stimuli." The thing for us to remember, in diagnosis, is that heredity fixes the possibilities of development; that we can not cause bones or other tissues to grow beyond their inherent size.

We know that particular conditions of malocclusion and jaw-forms run through certain families. Yet we can not assume this circumstance as proof of direct inheritance. It is probably due to some functional peculiarity connected with the environment. We know that the form of structure is the result of inherited possibilities molded by the force of surrounding conditions. Therefore, from the fact that we do inherit the possibilities of development, and in a sense inherit our environment, it is not strange that the same peculiarities of structural form sometimes appear in parents and their children.

A review of the great mass of evidence upon the transmission of conditions which affect the organization of the germ plasm, and predispose abnormalities of structure, would be irrelevant at this time. However, this reference is pertinent inasmuch as it further emphasizes the elements of variability and disharmony that must enter into any consideration of the structural form of an individual organism.

VIII. GENERAL CONCLUSIONS

If we summarize all this it means that, in the diagnosis for early treatment, our attitude is not the same toward all variations in the alignment and relations of the teeth. Even though they are equal in extent, their significance may be quite different. I refer, of course, to cases which are not extreme. A slight distal relation of the lower deciduous molars and canines is not viewed with the same suspicion as is lingual occlusion of the upper deciduous molars and canines. Nor is a lingual position of the lower permanent laterals as indicative of future deformity as a labial occlusion would be.

A slight posterior relation of the lower deciduous teeth soon after coming into occlusion may indicate retarded growth that will later correct

itself. The mandible is normally small at birth and we know, from clinical observation, that forward growth does take place unaided even after the eruption of the teeth. If the distoclusion is associated with abnormal lip function, then that is the thing to be treated, for it will interfere with the natural growth forces of other mandibular structures. The same is true in regard to the lingual position of the lower lateral incisors at the time of eruption. That is their normal position in the foetus. When growth in the size of the arch is slower than growth of the teeth, they naturally appear in lingual position. Clinical experience corroborates embryological evidence, for we know that lower lateral incisors do move into position unaided even though at one time there appears to be no room for them to do so.

On the other hand, such conditions as lingual occlusion of the upper deciduous molars, or labial occlusion of the lower centrals and laterals, which oppose the natural growth forces directed toward harmonious development, should be corrected as early as possible.

Although the illustrations I have given are few, I hope the idea is clear: that slight irregularities of the deciduous teeth, and of the permanent teeth during the transition period, should be interpreted in terms of growth and development, also in recognition of the law of normal variability and of the limits imposed by hereditary, environmental and constitutional factors; and that such irregularities should be considered abnormal only when they interfere with normal growth processes. When doubt exists, the nature of the problem bids us make careful records and observe.

It is not reasonable to place a pattern of perfection upon the dental arch of a child as a measure of its normality. Because a tooth can be moved is not sufficient reason for moving it.

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